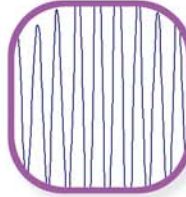
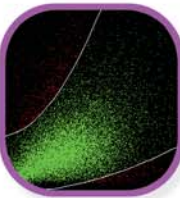


# A Sample of Phase Doppler Measurement Applications Providing Flexibility and Versatility



FLUID MECHANICS

Phase Doppler Applications

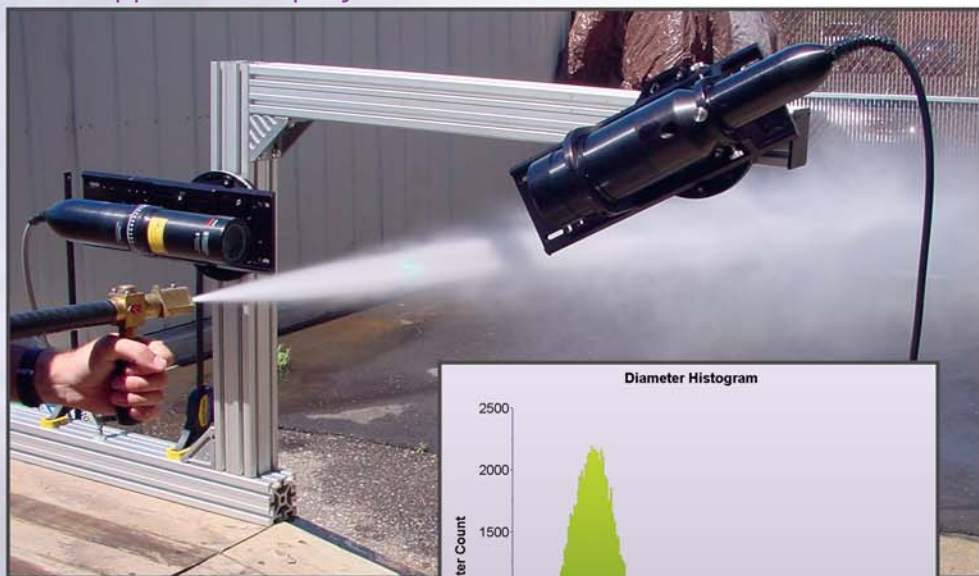


TRUST. SCIENCE. INNOVATION.

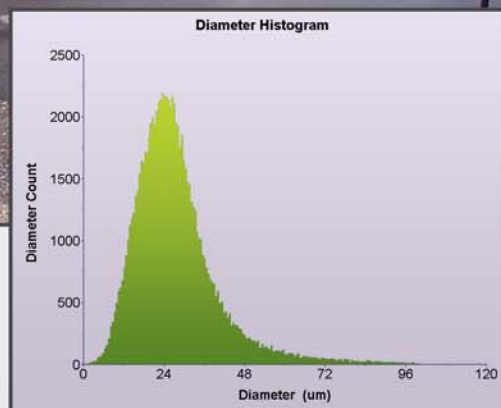
## Finding Solutions

When you need to know how efficient a spray is operating, or if it meets performance specifications, the solution is a phase Doppler system from TSI. TSI's Phase Doppler Particle Analyzer (PDPA) has a long history of versatility, from agricultural sprays to zero-gravity sprays. TSI's PDPA system has even measured droplet size spectra in hurricanes using a special research aircraft.

## Fire Suppression Spray



UHPS spray being measured with a PDPA system. Diameter histogram is shown on the right. UHPS equipment courtesy of Rosenbauer America Inc.

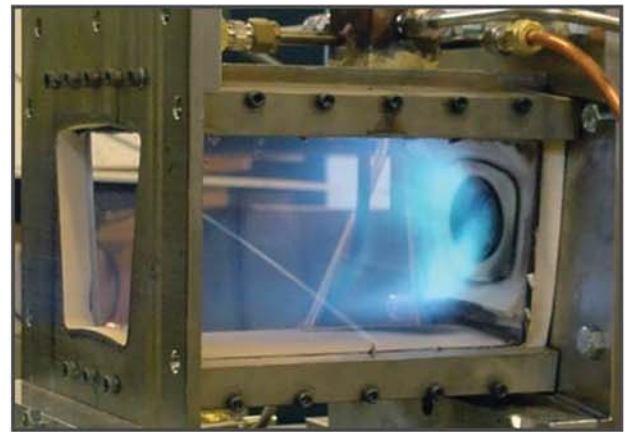


# Provide Solutions



## Aircraft Combustor Spray Measurements

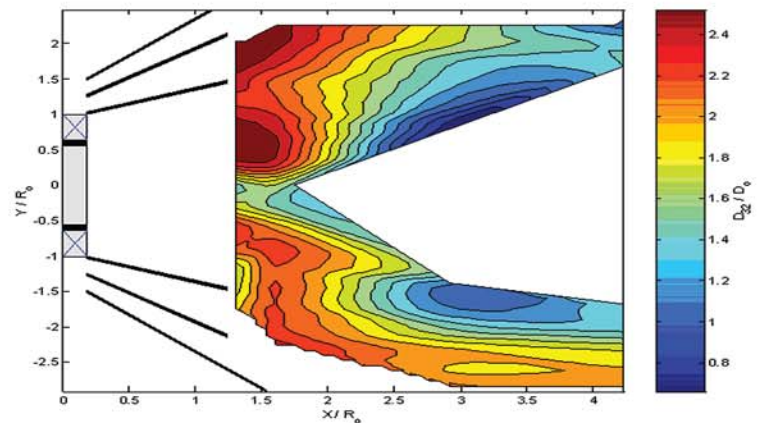
TSI's Phase Doppler Particle Analyzer has a long history of measuring fuel sprays, even in the presence of combustion. Recent innovations in combustor design create the need for new measurements. Measurements have been made in a combustor test rig with a FSA 4000 based system, including a traverse to sample at many locations in order to generate contour plots of Sauter Mean Diameter (SMD) as shown below. Results provide clues as to where the reaction zone is located and where fuel may be deposited on the walls. This information is important for understanding emissions characteristics, particularly under transient conditions.



Premixed lean combustor in operation (top) and measured Sauter mean diameter (bottom). Courtesy Jonathan Colby and Georgia Institute of Technology – See AIAA2005-4143 and AIAA2006-4919 for more details.

## Large Scale Fire Suppression Spray Measurements

Sprays touch our lives in many ways, from the morning shower to the fuel injectors in our car's engine. But for fire suppression sprays, achieving the right spray parameters can mean the difference between life and death. A new type of Ultra-High Pressure System (UHPS) was recently tested with a two-component PDPA system using a FSA 4000 signal processor and RV-2070 Receiver Probe. Water and water plus 3% foaming agent sprays were tested. Results showed very good initial atomization and larger droplet sizes for the non-foaming agent spray.



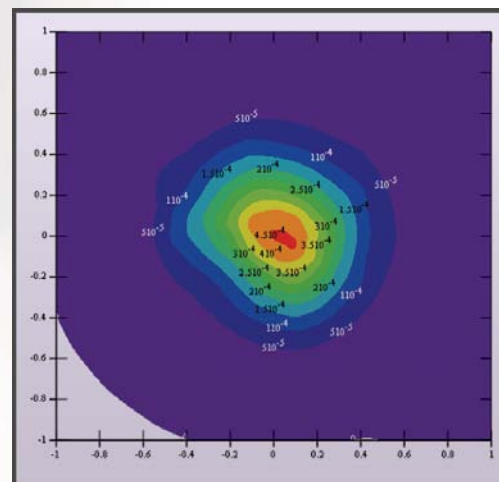


## Refrigerant Spray Measurements

Refrigerants are constantly evolving into more efficient and environmentally-friendly formulations. When the properties change, however, we need to seriously consider measurement of any related spray processes within the refrigeration system. High performance electronics use direct cooling by a refrigerant spray, and a standard FSA3500 based PDPA was used for this study. Flux is a key parameter related to heat load offloaded by the refrigerant, so accuracy is important. TSI's patented intensity validation and probe volume correction (PVC) helped deliver the required accuracy while maintaining the widest possible dynamic diameter range.



Refrigerant spray (above) and volume flux map (below). Very high accuracy was achieved with the TSI system. See ICLASS paper 06-163 for more details. Photo courtesy ISR Inc.



# Solve Problems



## Pesticide Spray Measurements

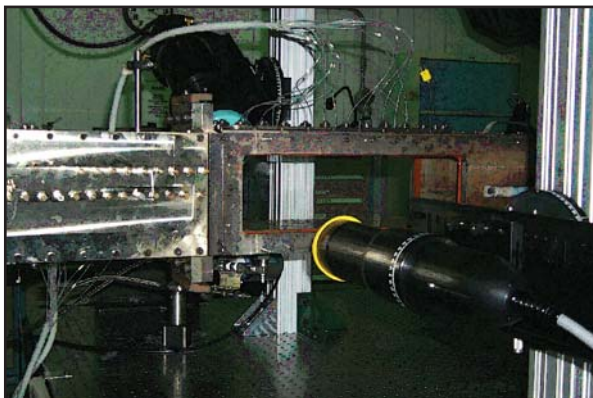
TSI's Phase Doppler Particle Analyzer (PDPA) is also being used to measure agricultural sprays, such as insecticide sprays, herbicide sprays, and pesticide sprays. Environmental contamination is a top concern, as is applying the chemical to the intended target in the correct form. Spray analysis with a PDPA yields time-varying data, diameter-velocity correlations, and flux data; all invaluable to the spray analyst. For these measurements a standard FSA 3500 based PDPA system is typically used.

## Mach 2 Spray Measurements

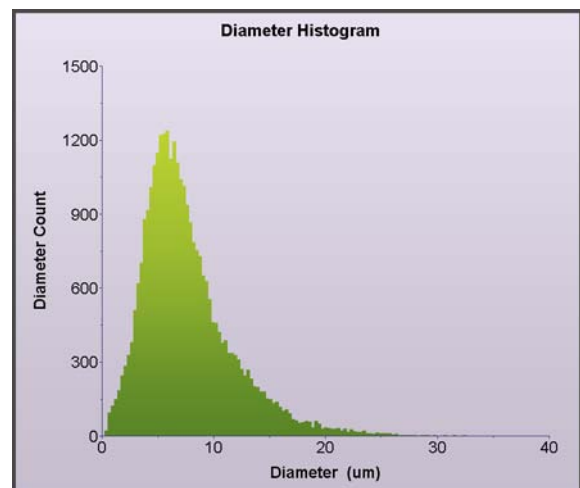
High-speed sprays and flows are another phase Doppler application area currently receiving attention. The continuous flow Mach 2 wind tunnel shown below is being used to study liquid hydrocarbon sprays with a FSA 4000 based PDPA system and RV2100 receiver. Different injection strategies are being tested to gain an understanding of droplet breakup and mixing. Further details are provided in AIAA paper 2004-0971.



Aircraft-based pesticide/herbicide applicator system (above) and measured diameter distribution of a phosphorothioate spray (below). Ground-based atomizers have also been measured with PDPA.



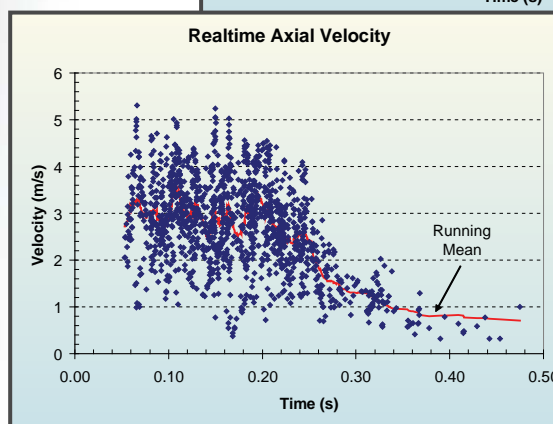
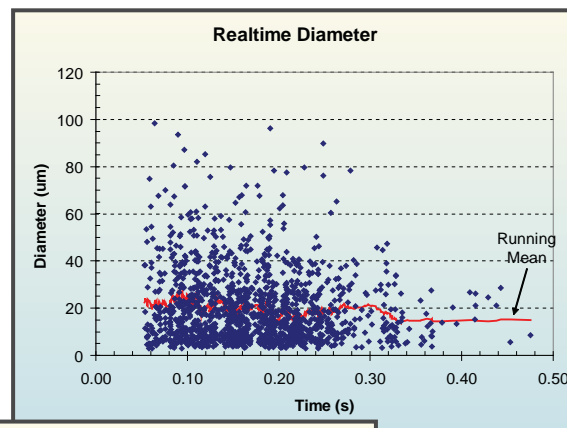
PDPA system being used to measure a spray in a Mach 2 crossflow. Courtesy Dr. Kuo-Cheng Lin This work was sponsored by AFRL/Propulsion Directorate at Wright-Patterson Air Force Base.





## Diameter & Velocity Trends of a Medical Inhaler Spray

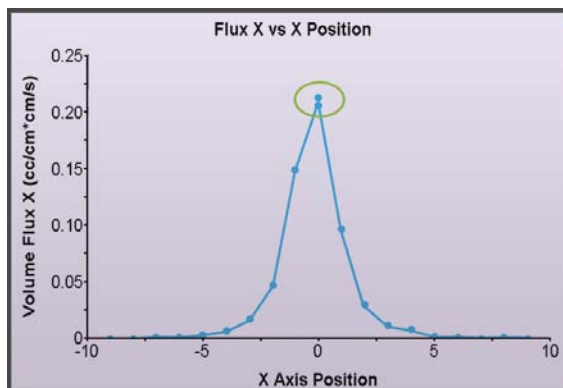
When sprays are used to disperse a medicine in the nose or mouth, we need to pay particular attention to the spray characteristics in order to ensure the safety of this technique. Metered Dose Inhalers (MDI) are commonly used to deliver asthma medication to the nose or mouth, for example. The opening and closing process of the MDI atomizer could introduce abnormally large droplets and it is possible that the spray quality degrades as the plume stops, resulting in very large droplets. This could present a hazard in terms of the volume of medication within each drop. A standard FSA3500 based PDPA was used to measure the medical inhaler. Diameter and velocity measurements were made on 10 to 20 spray events, as shown in the figure below.



# – Reliable Results

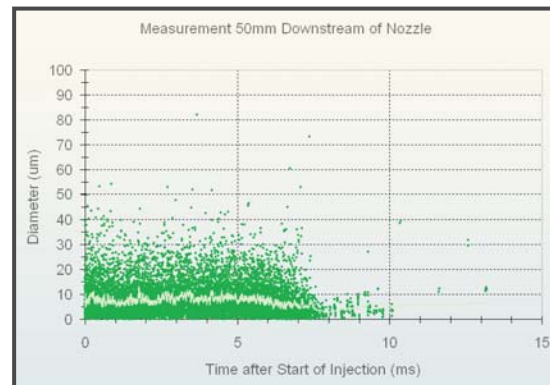
## Direct Injection Gasoline Fuel Spray Measurements

Beginning in the late 1990's automobile companies began to take advantage of significant gains in fuel economy and engine power by moving to a direct injection strategy, whereby the gasoline is injected directly into the combustion chamber. Spray characteristics, like volume mean and volume flux, become extremely important to avoid pollutant formation and engine failure. That's why many engine manufacturers have begun intensive measurement campaigns with Dense Spray optimized phase Doppler systems from TSI. Time-resolved and average diameters are available. TSI's patented Intensity Validation and Probe Volume Correction (PVC) provide unmatched data reliability. Combine that with TSI's huge dynamic diameter range and you have the ideal Phase Doppler System for direct injection gasoline fuel sprays.

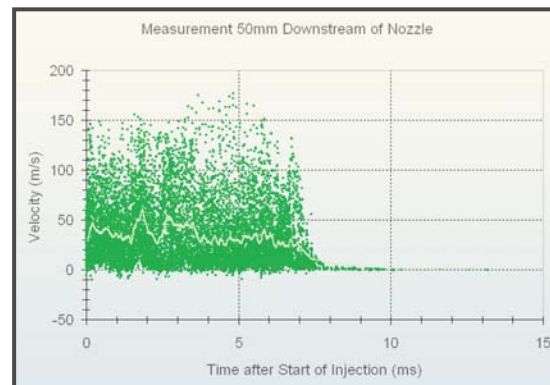


## Biodiesel Fuel Spray Measurements

As a renewable energy source, biodiesel is very attractive in its overall energy efficiency. Measurements were recently made of a soy-based fatty acid methyl ester (FAME) spray with a TSI PDPA system. An appropriate beam expander and the FSA4000 signal processor were used due to the high droplet density and short transit times. Results showed droplet diameters typical of petroleum based diesel fuel sprays for the injector used in this study. Further measurements are needed as injection equipment evolves into higher common rail pressures and piezo-injectors.



Velocity (above) and size (below) of a 100% biodiesel spray from a PLN type fuel injection systemž



## Standard PDPA System Components

LA70-5 and FBL-2 Laser and FiberLight Beam Generator System  
TM250 and XPDN50-I Transmitter Probe and Beam Expander  
RV2070 PDPA Receiver  
FSA 3500-2P Signal Processor  
PDM 1000-2P Photodetector Module  
6390A Computer with FlowSizer System Software Package  
T3D or T3DE Traverse System

## Dense Spray PDPA System Components

XPD50-E Beam Expander  
RV2100 PDPA Receiver instead of RV2070 Receiver  
SLT-025 Receiver Slit  
FSA 4000-2P Signal Processor instead of FSA 3500-2P Signal Processor

## High Speed PDPA System Components

FSA 4000-2P Signal Processor instead of FSA 3500-2P Signal Processor



TSI Incorporated serves a global market by investigating, identifying and solving measurement problems. As an industry leader in the design and production of precision instruments, TSI partners with research institutions and customers around the world to set the standard for measurements relating to aerosol science, air flow, indoor air quality, fluid dynamics and biohazard detection. With headquarters based in the U.S. and field offices throughout Europe and Asia, TSI has established a worldwide presence in the markets we serve. Every day, our dedicated employees turn research into reality.

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