# FSA 5800 MEASUREMENTS OF DIAMETER AND VELOCITY FROM A MONODISPERSE DROPLET GENERATOR & SPRAY NOZZLE

APPLICATION NOTE LDV-012 (A4)

## Phase Doppler Particle Analysis

Phase Doppler Particle Analysis (PDPA) is a technique where droplets passing through a laser beam crossing scatter the interference fringes and are recorded by an off-axis receiver in order to process the light signal and determine the particle diameter of each individual droplet passing through the ~100-micron measurement volume.

PDPA is capable of measuring both diameter and velocity at very high data-rates and for very dense sprays.

## Experimental Setup – MDG-100 Diameter Measurements

The Monodisperse Droplet Generator (MDG-100) is a device based on the principle of the vibrating orifice in which a steady stream of droplets of uniform diameter can be generated in a stream. By forcing a liquid through an orifice at a known flow rate, the orifice may be vibrated at a known frequency in order to "chop" the stream and produce droplets with very high repeatability. The droplet diameter may be determined by only knowing the volumetric flow rate and the frequency of the vibrating orifice by the following relationship:

$$D^3 = \left[\frac{6Q}{\pi f}\right]$$

Where $D$ is the droplet diameter, $Q$ is the flow rate, and $f$ is the frequency.

A photo showing the vibrating orifice head and the droplet stream can be seen in Figure 1.

**Figure 1.  MDG-100 Vibrating orifice head (*left*), and resultant droplet stream (*right*).**

For this set of experiments, the flow rate was 66.6 mL/hr and the frequency was 22.468 kHz which results in a theoretical droplet diameter of 116.285 microns.

A 2-D PowerSight transmitter was aligned with the laser beam crossing on the droplet stream in order to measure the velocity and diameter of the droplets produced. An FSA 5800 photo detector and signal processor was used to analyze the phase signals returned from an RV2070 receiver containing three detectors.

A photo of the experimental setup can be seen in Figure 2.


**Figure 2. PDPA system aligned for taking size and velocity data on an MDG-100.**

A photo of the MDG-100 droplet stream illuminated by the transmitted laser beams is shown in Figure 3.

**Figure 3. MDG-100 droplet stream illuminated by the PDPA laser beams.**

## Results – MDG-100 Diameter Measurements

The diameter measurement results of the MDG-100 measurements is shown in Figure 4. A total of 20,000 droplets were measured.

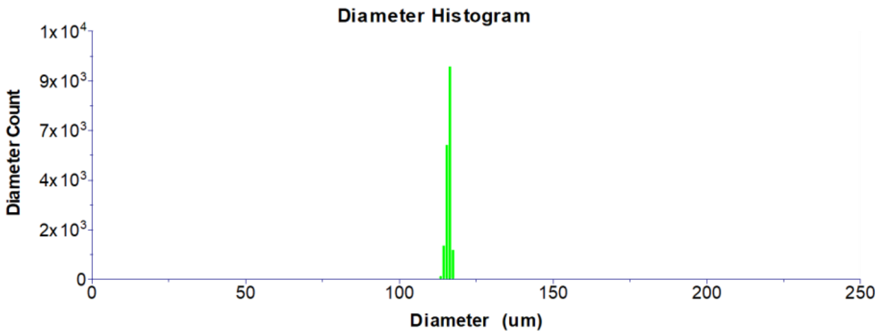


**Figure 4. Diameter histogram of the data collected from the MDG-100.**

The average diameter ($d_{10}$) was 116.294 microns compared to the theoretical value of 116.285 microns, a difference of 9 nanometers.

The MDG was operating at a frequency of 22.468 Hz, and the data-rate of the measurements was 22.468 Hz as well, indicating that every droplet produced by the MDG-100 during the measurement period was identified and measured. The burst efficiency, a measure of the number of valid to invalid measurements was 100%.

**Table 1. Diameter statistics from the MDG-100 measurements.**

| | |
|---|---|
| D10 (µm) | 116.294 |
| D20 (µm) | 116.2963 |
| D30 (µm) | 116.2986 |
| D32 (µm) | 116.3033 |
| D43 (µm) | 116.3079 |
| Diameter RMS (µm) | 0.7342 |
| Data Rate (Hz) | 22468 |

The diameter RMS for the total of 20,000 droplets was 0.7342 microns, indicating a very monodisperse droplet stream.

## Results – Spray Measurements

A 2-D PDPA system was also used to measure the droplet diameter and velocity of a spray nozzle. A photo of the spray nozzle and PDPA measurement system is shown in Figure 5.

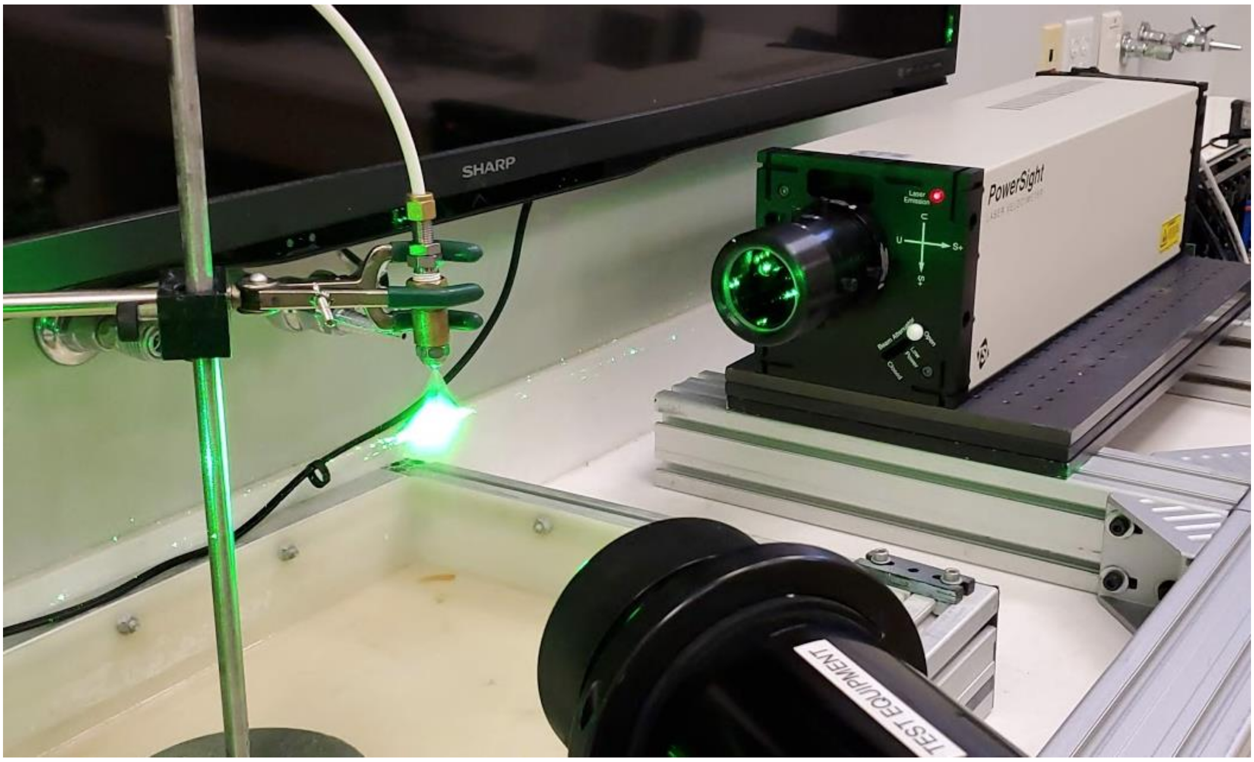


**Figure 5. Photograph of the experimental setup.**

The measurement region was 50 mm downstream of the nozzle along the center axis. A screenshot of the measurement results can be seen in Figure 6.

Intensity validation was used to verify the measurements. The $d_{10}$ was 42.23 microns and $d_{32}$ was 90.98 microns. The average velocity was 12.1 m/s.

Probe volume correction (Fandrey et al., 2000) was also applied to the data in order to account and correct for the inherent nature of probe volume measurement size dependence on particle diameter. The corrected diameters for $d_{10}$ and $d_{32}$ were 42.17 and 90.96 microns, respectively.

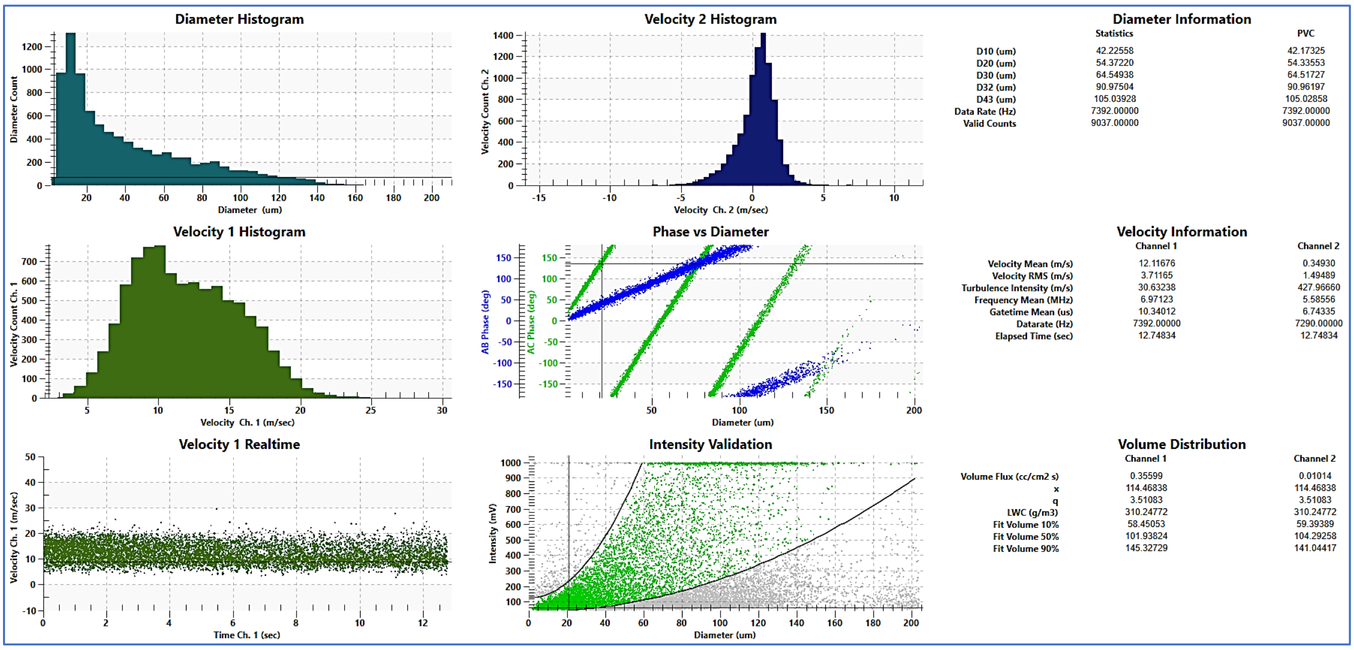


**Figure 6. Screenshot of the FSA BurstPro™ Flow and Particle Analysis software displaying the results of the spray measurements.**

# Conclusion

A TSI® PDPA system was used to measure the output of an MDG-100 monodisperse droplet generator. The mean diameter ($d_{10}$) measured was 116.294 microns compared to the theoretical value of 116.285 microns as determined by the flow rate and vibrational frequency of the monodisperse droplet generator. Clearly the resultant mean diameter matched the theoretical with a very high degree of accuracy (9 nm).

With the accuracy of the system confirmed, the same system was also used to take measurements along the central axis downstream of an agricultural spray nozzle. The probe-volume-corrected measurements of the spray indicated a mean diameter ($d_{10}$) of 42.17 microns, and a Sauter Mean Diameter (SMD) of 90.96 microns.

The PDPA system utilizing the FSA 5800 photo detector and signal processor provides excellent diameter measurement accuracy as indicated by the measurement results from the monodisperse droplet generator (MDG-100). The applicability of the system to a typical spray nozzle was also demonstrated, giving highly accurate diameter and velocity measurements individually, for thousands of droplets crossing through the measurement volume.

# References

Fandrey, Chris & Naqwi, Amir & Shakal, Joseph & Zhang, Hai. (2000). "A Phase Doppler System for High Concentration Sprays." *10th International Symposium on Applications of Laser Techniques to Fluid Mechanics.*

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|---|---|---|---|
| **USA** | **Tel:** +1 800 680 1220 | **India** | **Tel:** +91 80 67877200 |
| **UK** | **Tel:** +44 149 4 459200 | **China** | **Tel:** +86 10 8219 7688 |
| **France** | **Tel:** +33 1 41 19 21 99 | **Singapore** | **Tel:** +65 6595 6388 |
| **Germany** | **Tel:** +49 241 523030 | | |


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