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Sandia Is Developing a Doppler Global Velocimetry System to Understand Fundamental Wind-Turbine Wake Phenomena

Wind-turbine wakes lead to lower power production *and* increased loading on downstream turbines by reducing incoming velocity and increasing turbulence contained within the wakes. Detailed wake measurement will improve the understanding necessary to improve wake modeling and consequently support reducing cost of energy (COE) at the plant level.

Sandia is developing a DGV wake-imaging system to provide detailed wake velocity-measurement capabilities. The project will demonstrate the viability of measuring turbulent-flow structure formation and development near the rotor at temporal and spatial scales not accessible by current techniques such as LIDAR and particle image velocimetry (PIV).

Current scanning LIDARs are capable of measuring only the average velocity and turbulence statics over a large area along the path of the laser scanning beam. This results in poor spatial resolution due to the pointwise measurement and the nature of the LIDAR technology. Also, it does not offer an instantaneous realization of turbulent structures, which is key to understanding turbulence physics in detail.

PIV is an optical flow-visualization method used to obtain instantaneous-velocity measurements and related properties in fluids. The fluid is seeded with tracer particles which, for sufficiently small particles, are assumed to faithfully follow the fluid's flow dynamics. The fluid with entrained particles is illuminated by a thin laser sheet to make the particles visible, and a camera captures an instantaneous snapshot of the flow field. The seeded-particle motion is used to calculate speed and direction (the velocity field) of the flow under study.

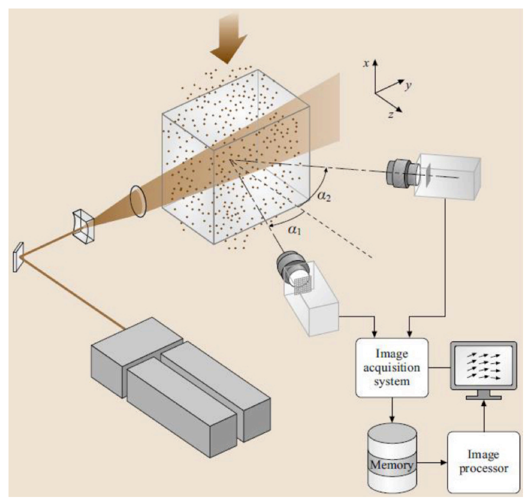

Figure 1. Schematic of a stereoscopic PIV setup.

PIV's result is a series of 2D flow fields with very high spatial resolution. A stereoscopic technique (Figure 1) can be used to capture the velocity in 3D over the entire area of interest. PIV is capable of providing quantitative information on coherent flow structures, improving flow-field understanding. *Unfortunately* PIV's working distance is limited, which has relegated its use primarily to wind tunnels—where high particle seeding density can be achieved.

A method better suited for coherent turbulent structure large-area measurements is Doppler global velocimetry (DGV) or planar Doppler velocimetry. DGV methods use a combination of PIV- and LIDAR-like techniques, and measures the Doppler shift of light scattered from tracer particles within a flow field illuminated by a laser sheet (Figure 2). The Doppler shift is derived at each pixel of an image using an iodine vapor cell as a molecular filter that converts the frequency variations of the scattered light into intensity variations. With this method, PIV results can be obtained simultaneously. DGV resolution is much higher and thus better suited for larger areas of interest.

DGV was originally developed by Dr. James Meyers at NASA. As we develop our DGV wake-imaging system, Sandia is using Dr. Meyers as an expert advisor.

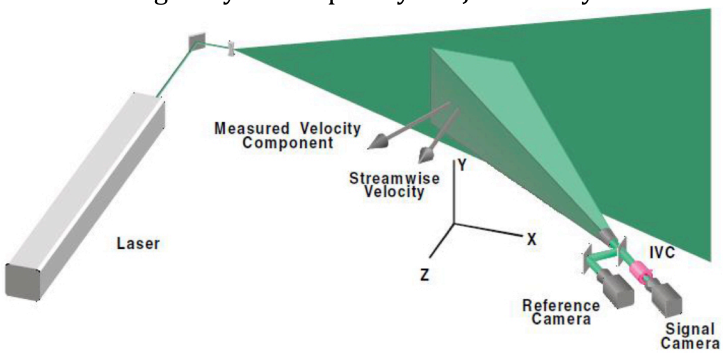

Figure 2. Diagram of DGV optical configuration.

The Scaled Wind Farm Technology (SWiFT) facility's eventual DGV system will measure the 3D coherent wake structures over relevant time scales with high spatial resolution—providing the experimental data to help us understand fundamental wind-turbine wake phenomena and to validate computational codes and design tools.