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Measuring Ultrafast Turbulent Flow Characteristics using Time-Stretch Imaging

Mohammed Bukhalaf, Emin Issakhanian, and Hossein Asghari*
Loyola Marymount University, Los Angeles, CA, 90045,
e-mail: mbukhala@lion.lmu.edu; Emin.Issakhanian@lmu.edu; masghari@lmu.edu

Turbulent flow is a type of gas or liquid flow in which the fluid undergoes irregular fluctuations, or mixing, in which the speed of the fluid at a point is continuously undergoing changes in both magnitude and direction [1]. Some applications in which characteristics of turbulent flow are important include blood flow in arteries, oil transport in pipelines, lava flow, atmosphere and ocean currents, the flow through pumps and turbines, and the flow in boat wakes and around aircraft-wings.

Time-stretch imaging is an optical bright-field imaging method capable of operating at speeds well beyond million frames per second [2]. In this method ultrashort pulses are spatially diffracted using a diffraction grating and the resulting spectral rainbow is subjected to the spatial object under test. Information about the spatial object is encoded into the optical pulse spectrum. Time-stretch dispersive Fourier transform is used then to map the single-shot consecutive pulse spectra, contain the object spatial information, to the time domain where they can be captured using an ultrafast digitizer. Digital processing is used to reconstruct the image using captured spectra.

In this work, we report the first demonstration of measuring turbulence flow characteristics using time-stretch imaging. In particular, we analyze captured pairs of images with minimal inter-image time to measure movement of air around the blades of a fast rotating fan. The time stretch imaging system used operates at 100 3illion lines per second. The new technique proposed in this work could open unprecedented opportunities for researchers interested in turbulence flow characteristics.

1. G. Batchelor, “Introduction to Fluid Mechanics,” ISBN: 9780511800955, 2000.

2. K. Goda; K. K. Tsia & B. Jalali, “Serial time-encoded amplified imaging for real-time observation of fast dynamic phenomena,” Nature. 458: 1145–9, 2009.