Particle Image Velocimetry Applications Using Fluorescent Dye-Doped Particles

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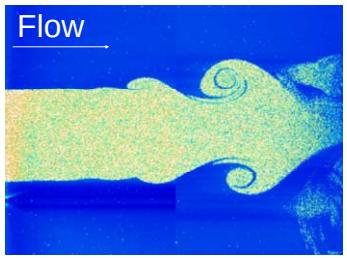
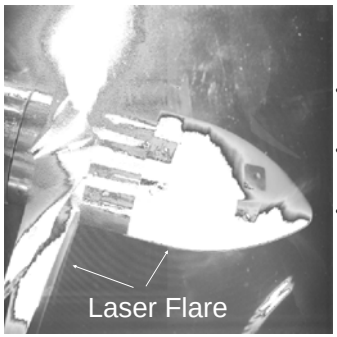
Overview and Background

- The present work solves the problem of laser flare in Particle Image Velocimetry (PIV) by using fluorescent particles.
- PIV is a laser flow diagnostics technique used to map a velocity field in a moving fluid.
- In PIV, a camera takes two images of seed particles in the flow illuminated by a laser causing Mie scattering. Velocity is calculated from the displacements of the particles.
- PIV is widely used in the aerospace, mechanical engineering, and medical fields.





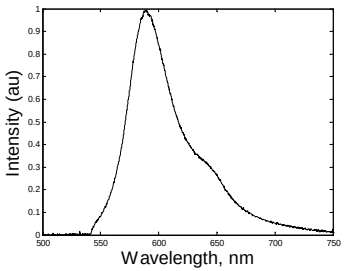
Motivation

- A major problem with PIV is laser flare, coming from reflections off of solid objects in the flow.
- In regions of laser flare, particles cannot be tracked and velocity cannot be calculated.
- Surface treatments are available for object surfaces, but they are expensive, fragile, labor intensive, and/or potentially carcinogenic.

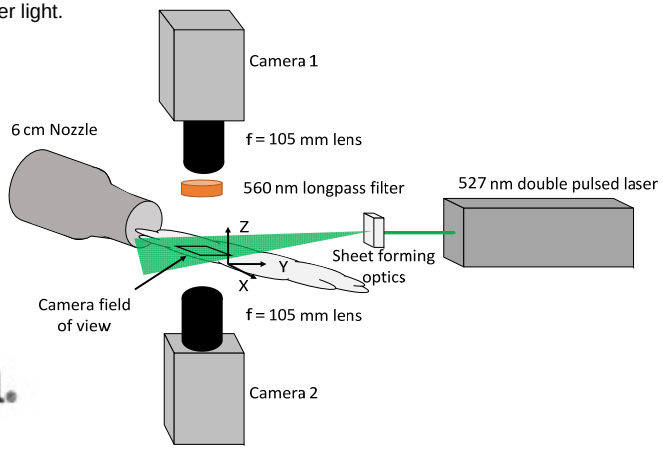
Alexander, W. N., Devenport, W., Wisda, D., Morton, M., and Glegg, S. A. L., "Sound Radiated from a Rotor and Its Relation to Rotating Frame Measurements of Ingested Turbulence", 20th AIAA/CEAS Aeroacoustics Conference, Atlanta, GA, July 16-20, 2014, AIAA-2014-2746.

Experimental Setup and Theory

- The present research uses 1 micron plastic microspheres doped with Kiton Red 620 fluorescent dye.
- Fluorescent light is emitted at a higher wavelength than the laser light, due to the Stokes shift.
- An optical filter is used to block all laser light.



Measured emission spectrum of Kiton Red 620 doped polystyrene latex microparticles



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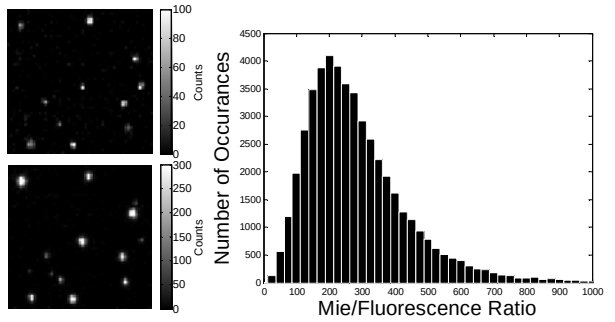
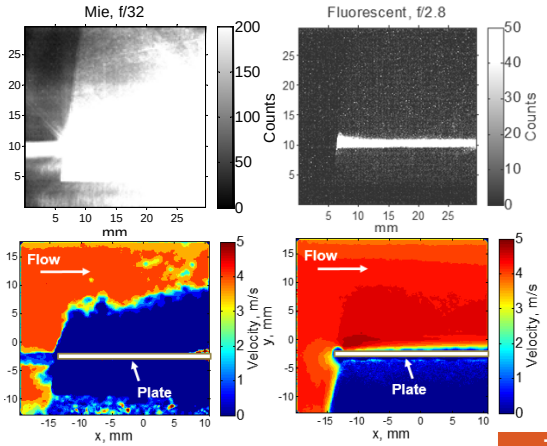
Experimental Results

- Two cameras imaged the same region of flow: one using fluorescent PIV, the other using traditional PIV methods.
- The fluorescent signal was measured to be 100-225 times lower than Mie scattered signal from particles
- With appropriate laser strength and optics, this signal difference can be easily overcome, and fluorescent particles can be used in any PIV application.



50 x 50 pixel fluorescence image (top left) and Mie scattered image (bottom left). Resulting signal ratios on right.



- Tests were run with an aluminum flat plate placed in the flow.
- The resulting laser flare is easily visible in the raw image (top left).
- In this test, flow velocities could not be measured within 5-10 mm of the plate surface (bottom left).
- The use of fluorescent light eliminates all of the laser flare except for particles stuck on the plate surface (top right).
- Flow velocities can be calculated all the way down to the plate surface (bottom right)

- Processed data indicates that the fluorescent PIV technique can lead to 63 times fewer invalid flow velocity data points

Technique	Percent Valid Data
Fluorescence	99.0%
Mie	36.6%

* A typical "good" value in PIV is 95% valid.

Publications and Future Work

- Current Publications:
  - Petrosky B, Maisto P, Lowe K T, André M, Bardet P, Tiemsin P, Wohl C and Danehy P, "Particle Image Velocimetry Applications Using Fluorescent Dye-doped Particles," in *AIAA Scitech*, Kissimmee, 2015.
- Future work:
  - Expand testing to include larger flow facility applications
  - Optimize particle doping techniques for greatest fluorescent light signal