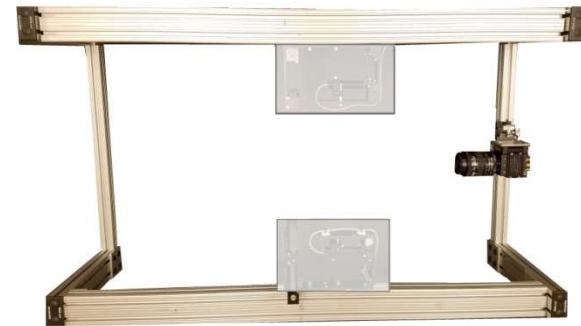


Statistical Pattern Imaging Velocimeter

Introduction and Overview



En'Urga Inc.

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765-463-7004

<http://www.enurga.com>



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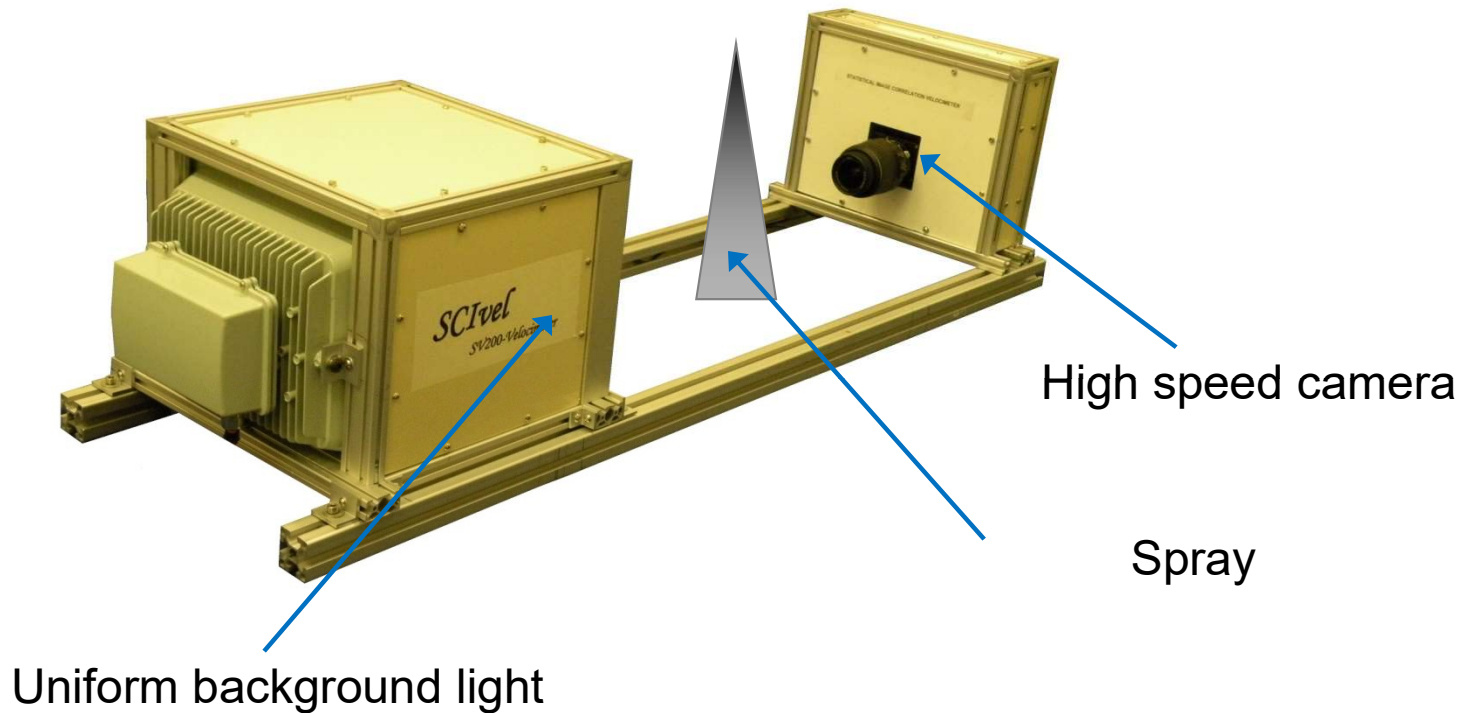
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Background

- Several instruments available on the market
- Single point measurements obtained using LDV, PDA, hot wire anemometry
- For planar velocities, PIV is the most commonly used instrument (requires capture of images of individual particles)
- Statistical Pattern Imaging Velocimetry (SPIV) does not require resolution of individual particles
- SPIV requires distinct patterns in the flow
- Provides spray angles (as per SAE J2715 standard) and full flow field velocity

Basic Arrangement of SPIV



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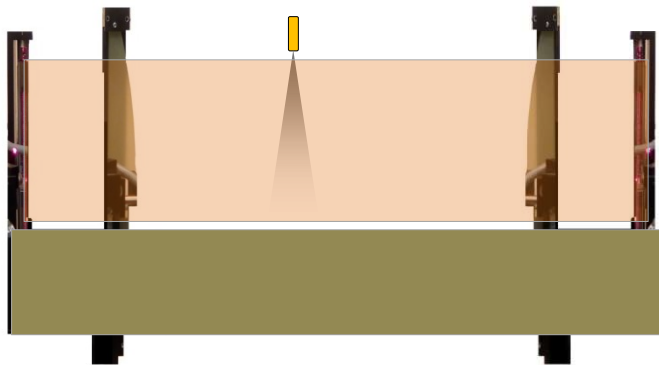


Advantages of SPIV

- Does not rely on imaging individual particles
- Computes statistical correlation between patterns over the entire pixel range
- Can be implemented using any high speed camera
- Computational time required for full flow field velocity is approximately 5 minutes
- User interface operated by technician
- Uncertainty of estimated velocity < 5%
- Can be used for flames, sprays, and smoke particles

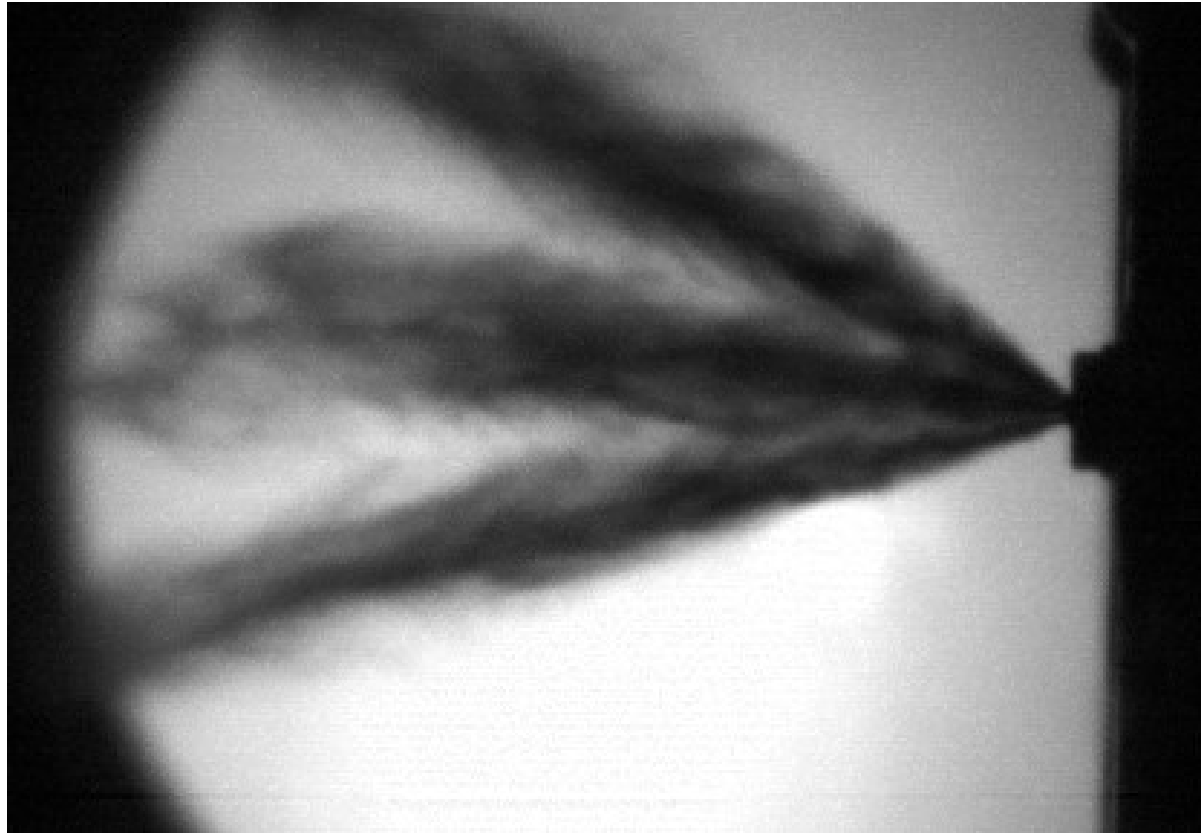
Limitations

- Requires high speed camera (at least 10 KHz for velocities up to 100 m/s)
- For shadowgraph videos requires short depth of view for focusing lens
- For laser sheet images, lighting from both sides is better
- All velocities are volume averaged



Suggested lighting arrangement for opposed laser sheet Mie imaging (available for 250 mm height , 1 Watt from En'Urga Inc.)

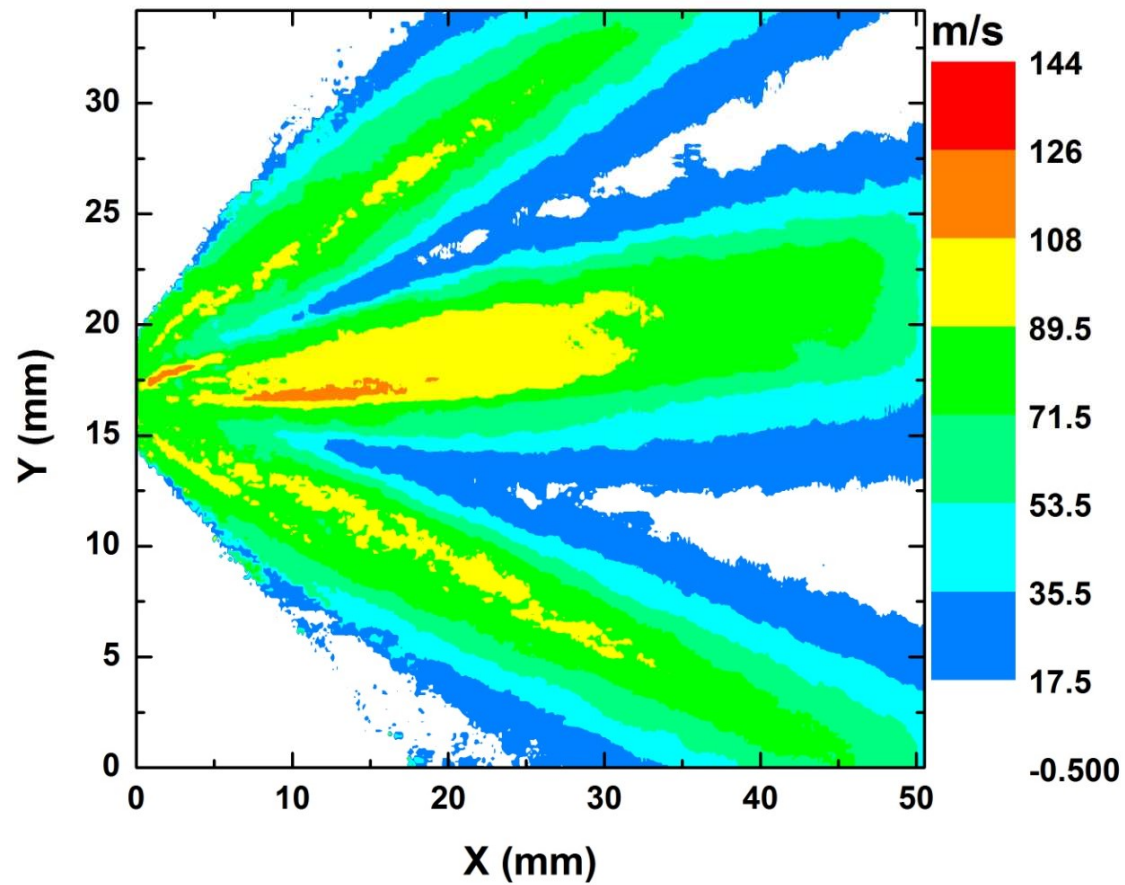
Sample Applications (GDI Injector)



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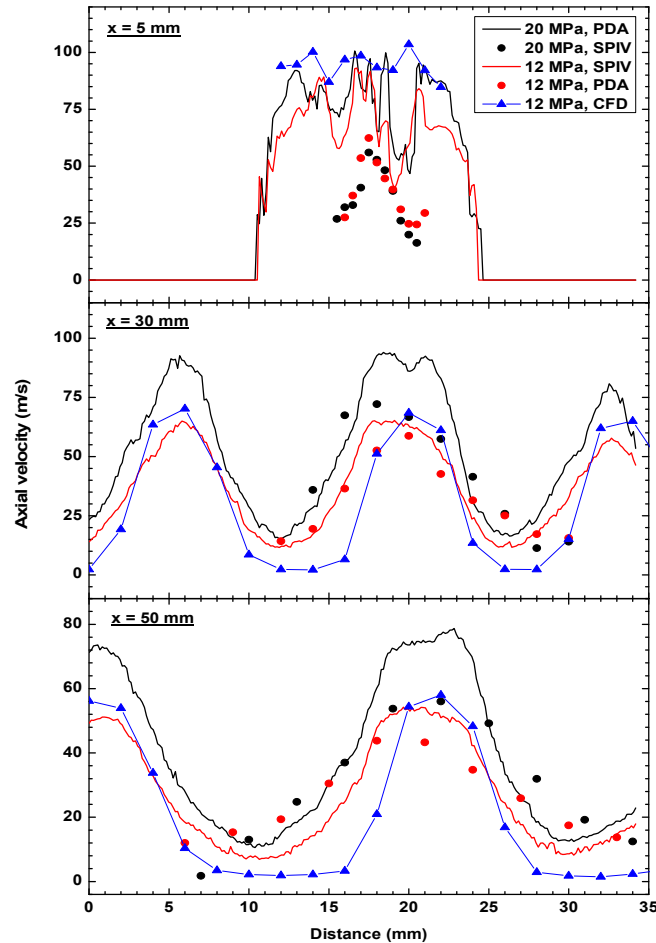
Full Flow Field Mean Axial Velocity



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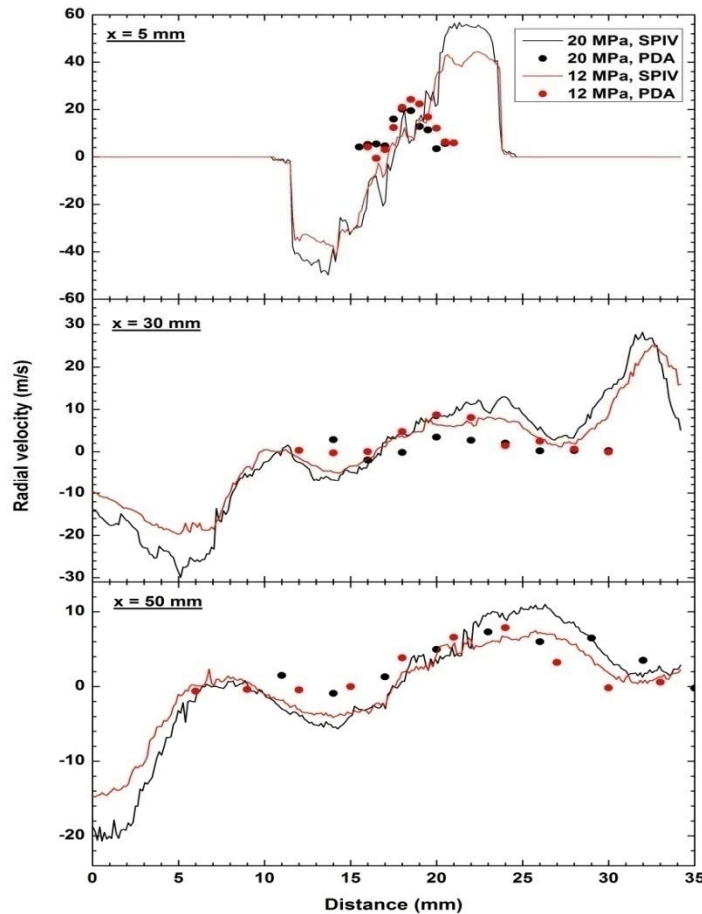
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Comparison with PDA (1)



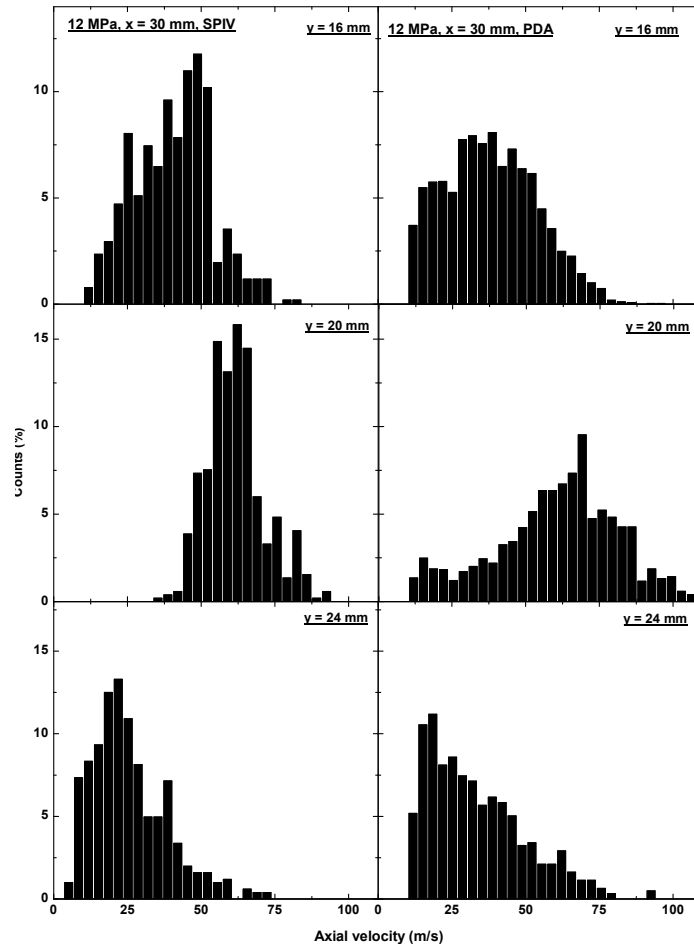
- GDI injector
- PDA fails near injector due to high obscuration
- 10000 Hz camera
- Good agreement at lower positions
- Full planar axial velocity available
- Agrees with CFD computations near the injector

Comparison with PDA (2)



- GDI injector
- PDA fails near injector due to high obscuration
- 10000 Hz camera
- Good agreement at lower positions
- Full planar radial velocity available

Comparison with PDA (3)



- PDFs of Axial velocity
- PDA values on right
- SPIV on left
- More Low values for PDPA
- PDPA cannot obtain data during injection event due to high obscuration

Sample Results (Furnace nozzle)



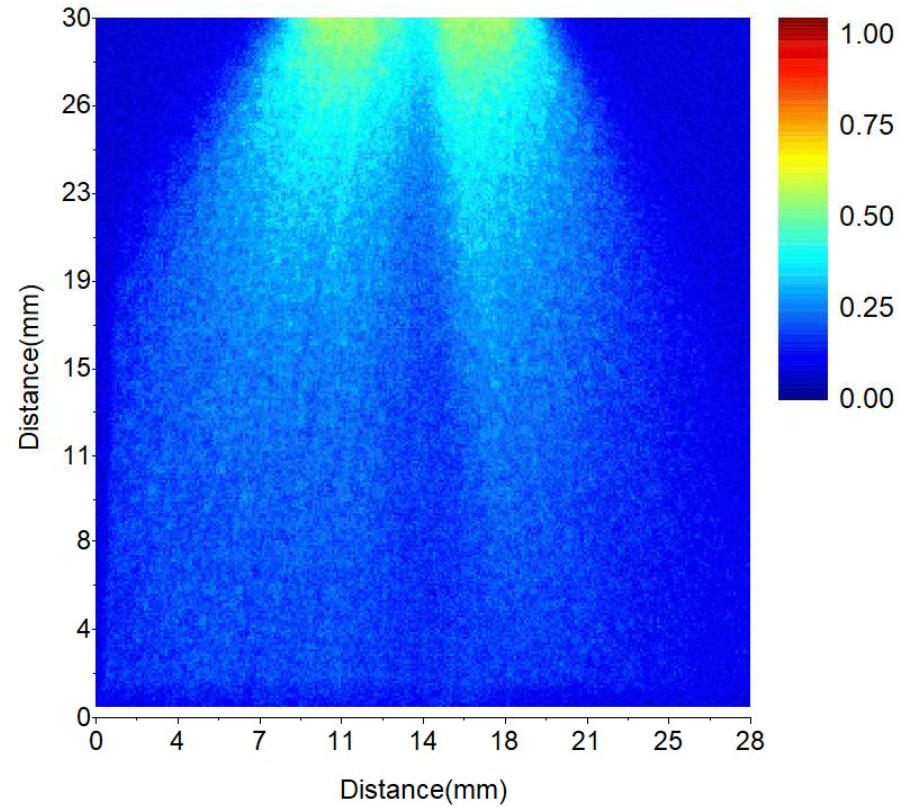
Sequence of 2000 images obtained over a period of 20 ms is analyzed to provide velocity



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Correlation Coefficient



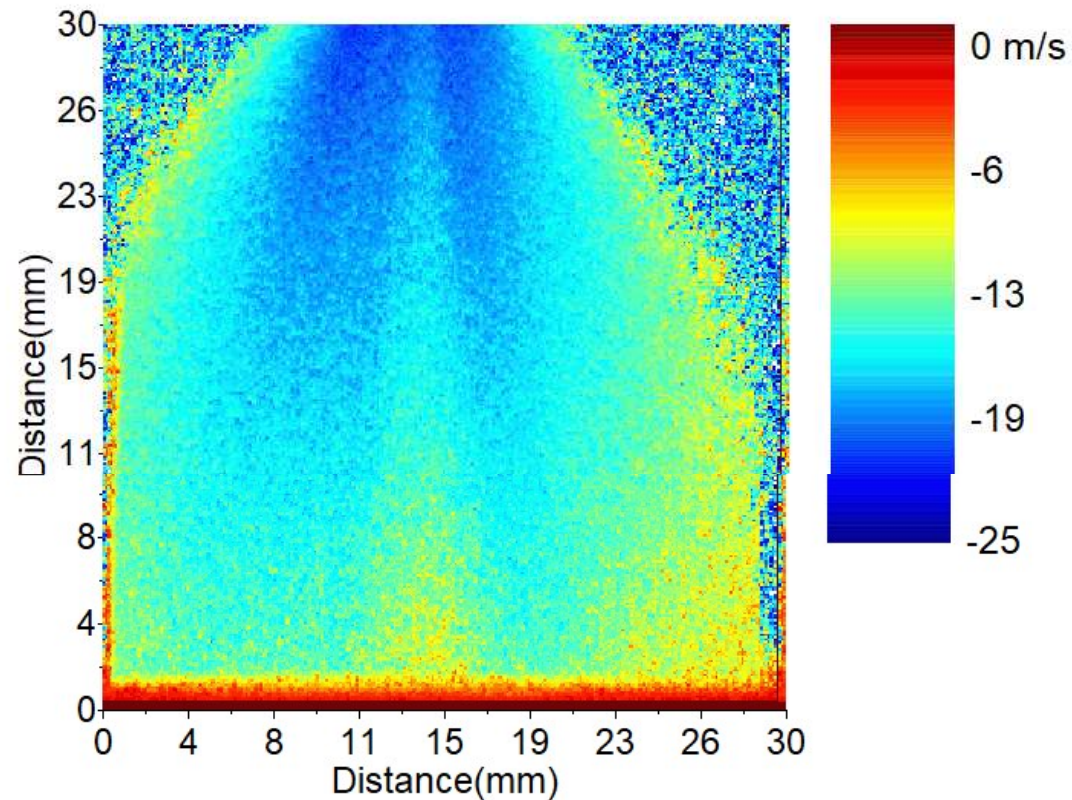
Peak correlation of 0.50. This can be improved with better lighting



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Axial Velocity



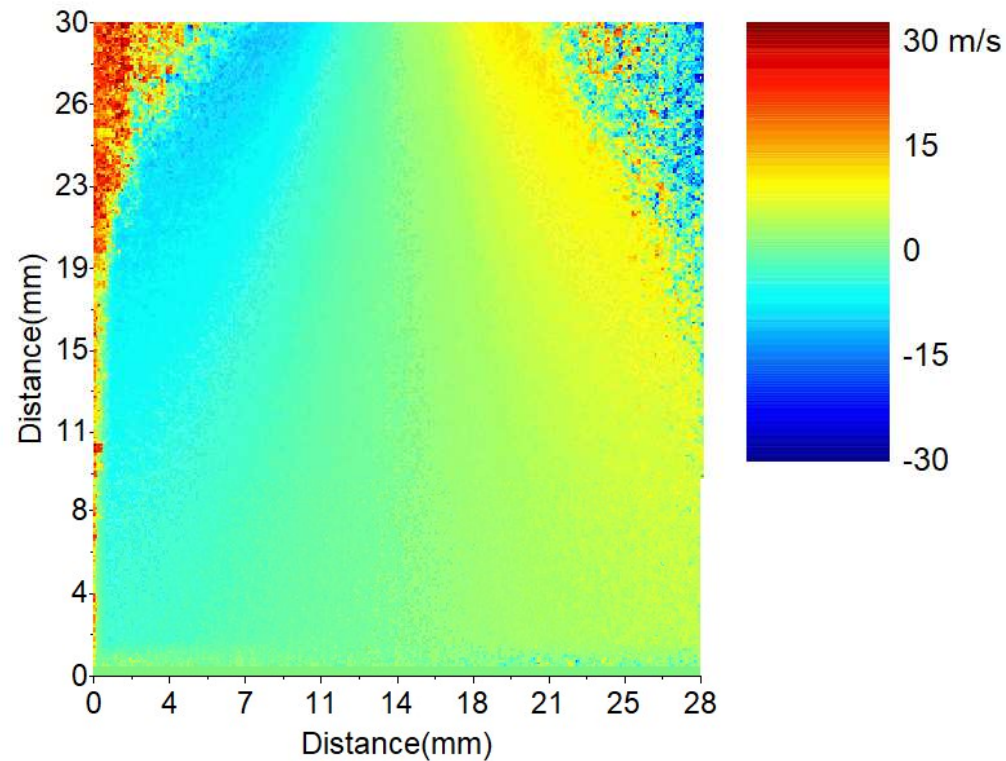
Axisymmetric profiles. Peak values of ~ -15 m/s



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Radial Velocity



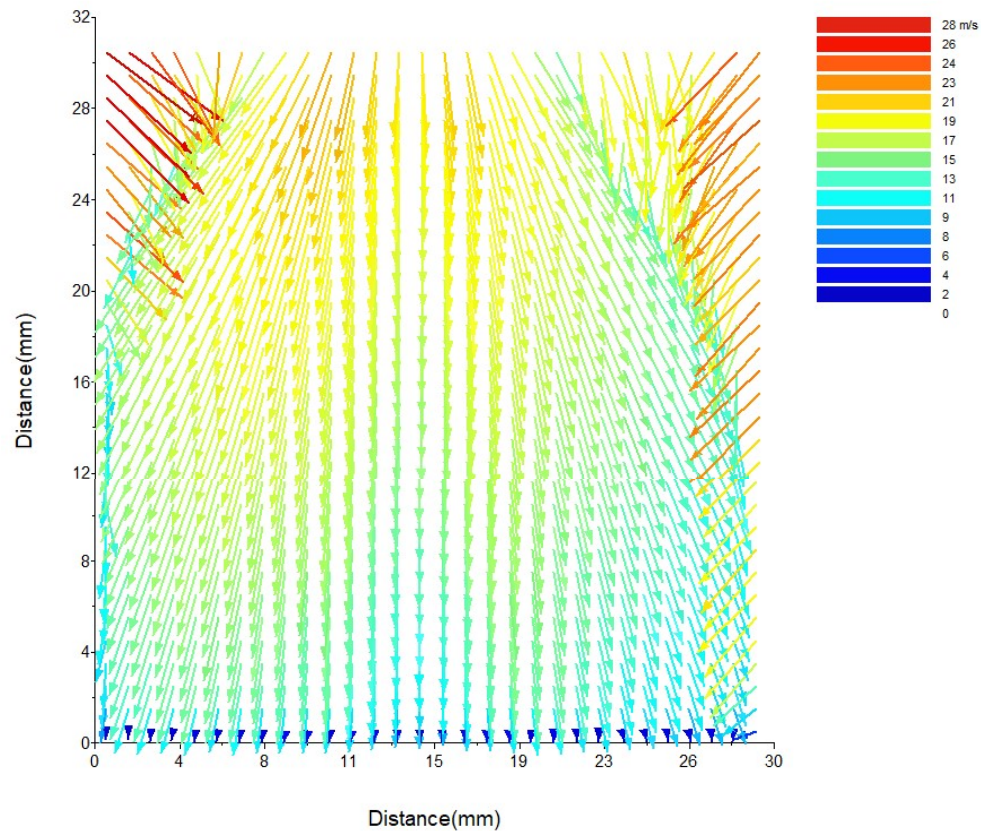
Axisymmetric profiles. Peak values of ~ -8 m/s



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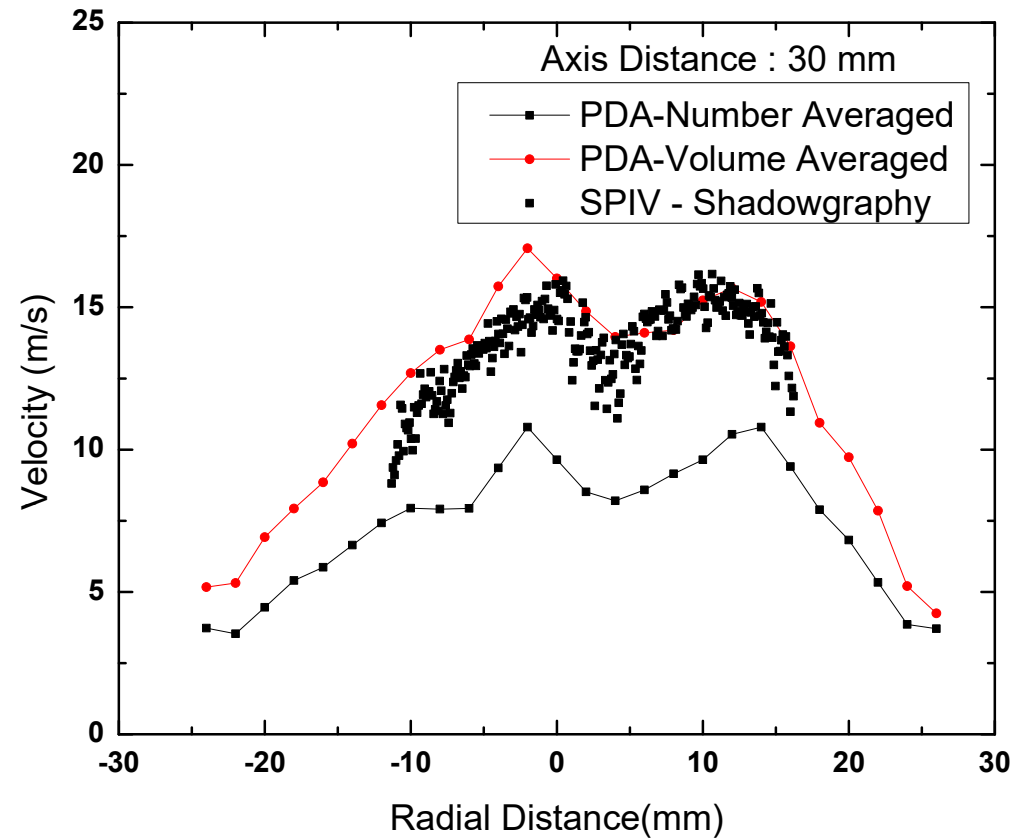
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Velocity Vectors



Some noise at the edges. Similar to PIV and PDA

Validation



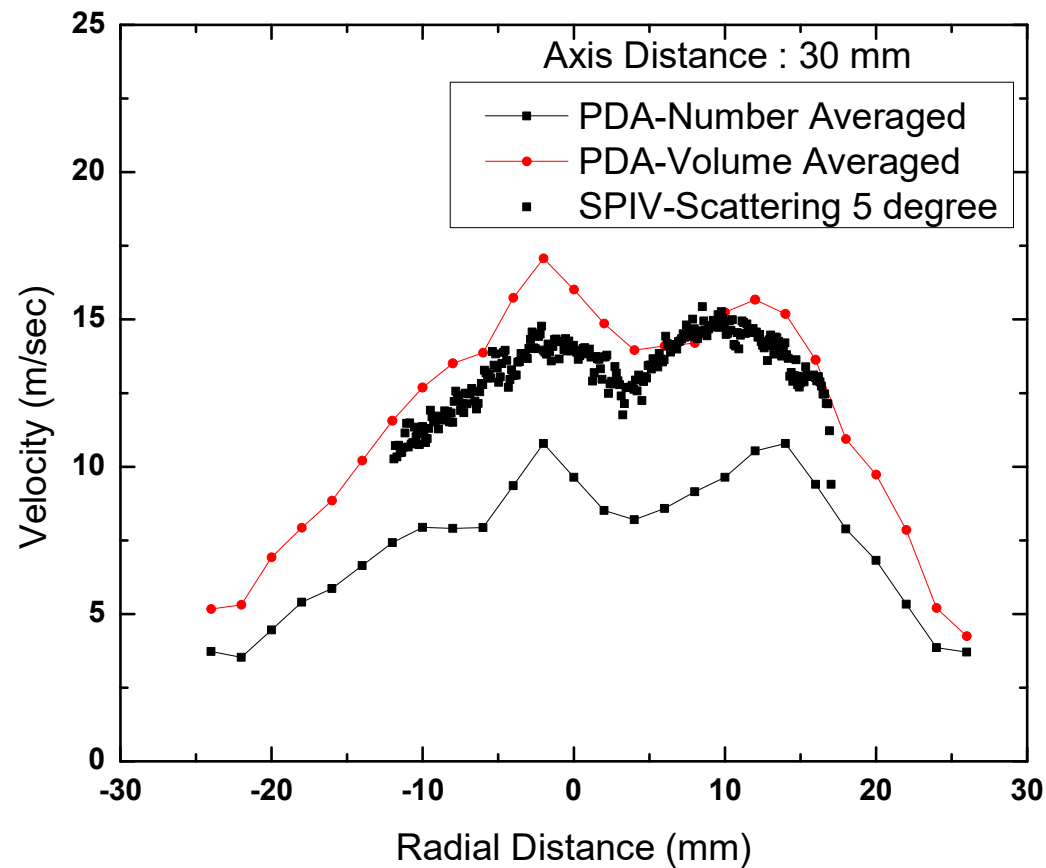
Measured velocity is volume averaged.



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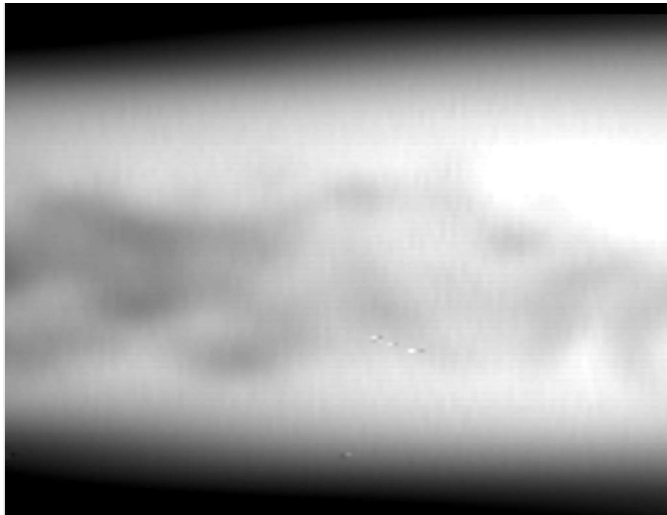
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Validation (2)

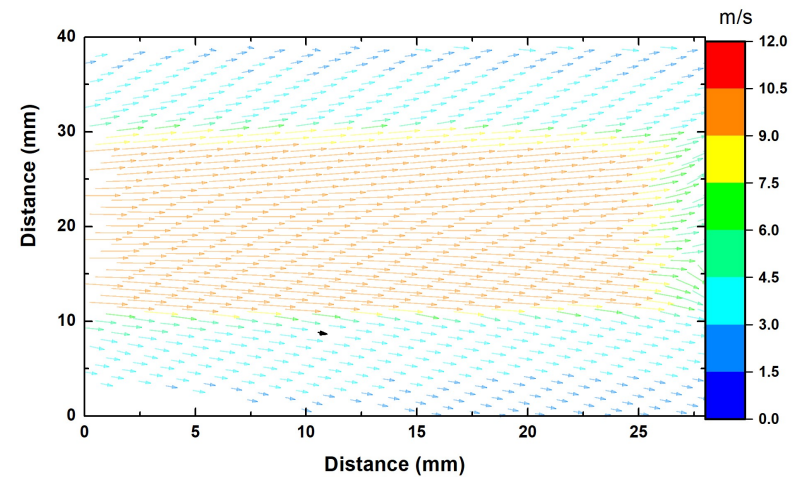
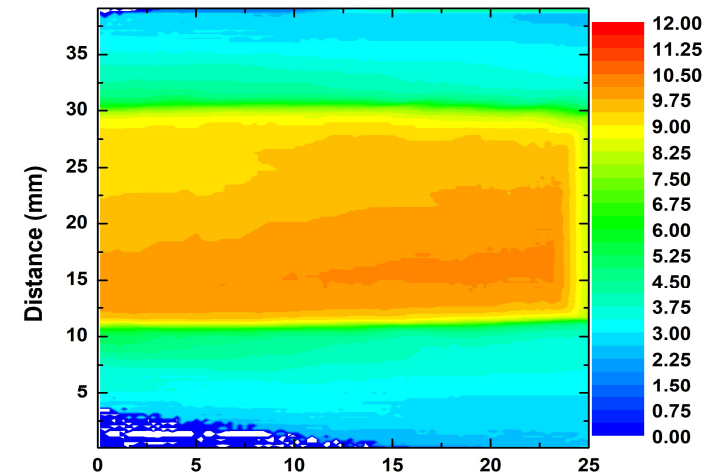


Similar results with Mie-scattered images.

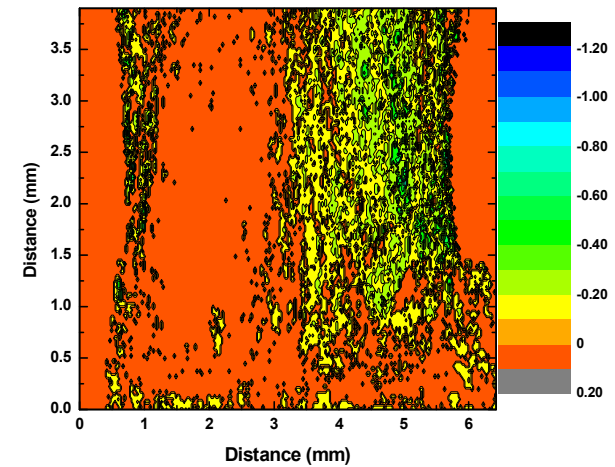
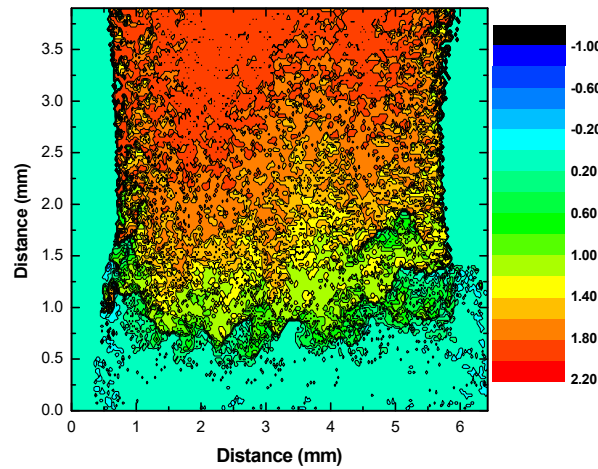
Velocity measurement in a flame



Horizontal flame video (B/W)
Axial velocity contour map
Velocity vector map



Velocity measurement in monopropellant plume



Sample X and Y mean velocities



Possible configurations for SPIV

- Can use any user specified camera
- Shadowgraphy, laser sheet, or LED
- Easy to set up
- Can be used for flame velocities also
- Extensive customization of GUI
- Individual components or full system
- Velocity uncertainty estimated at 5% (for 3000 frame video)
- Uncertainty decreases with video length



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