

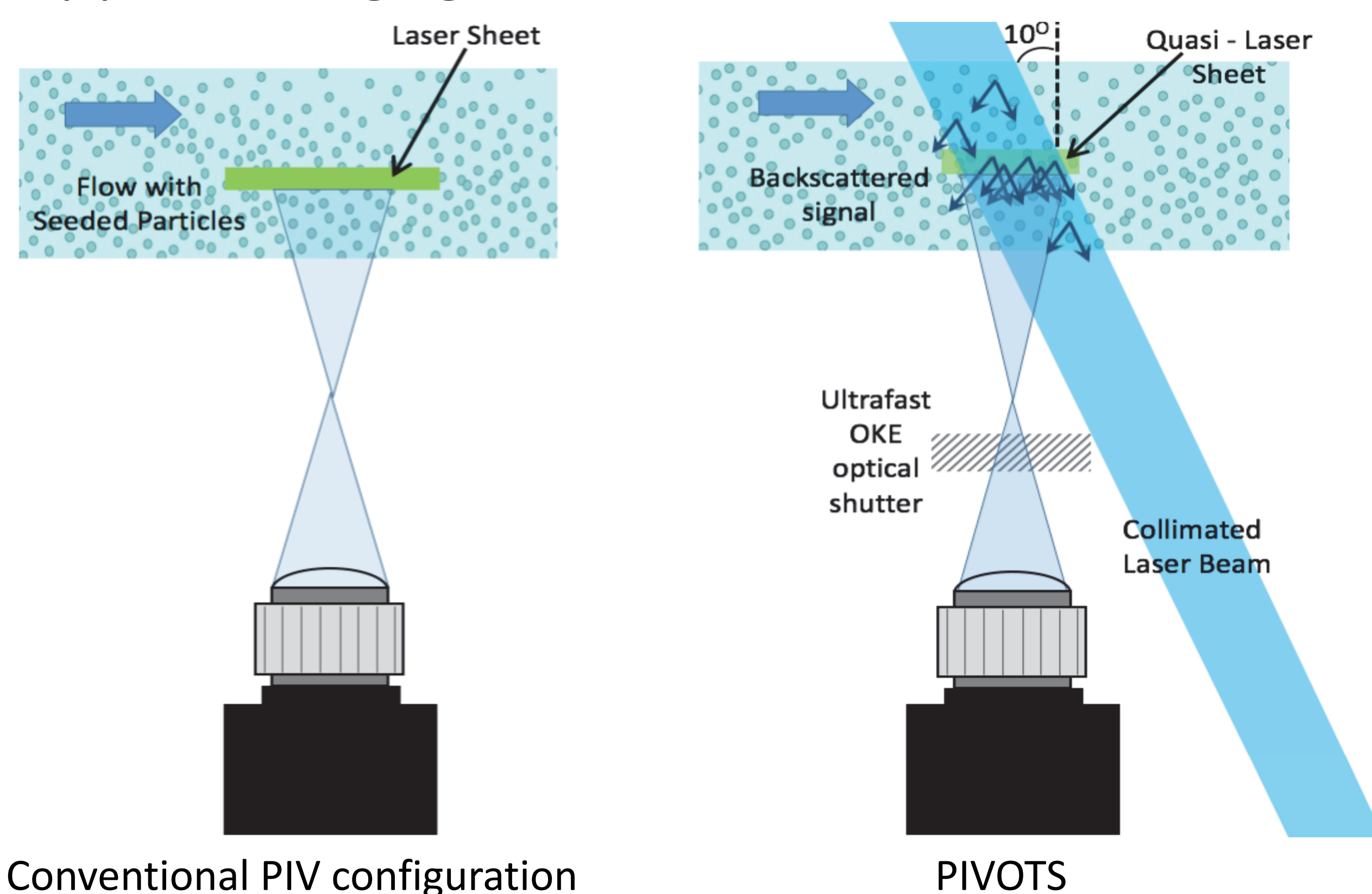
Particle Image Velocimetry using Optical Time-of-flight Sectioning (PIVOTS)

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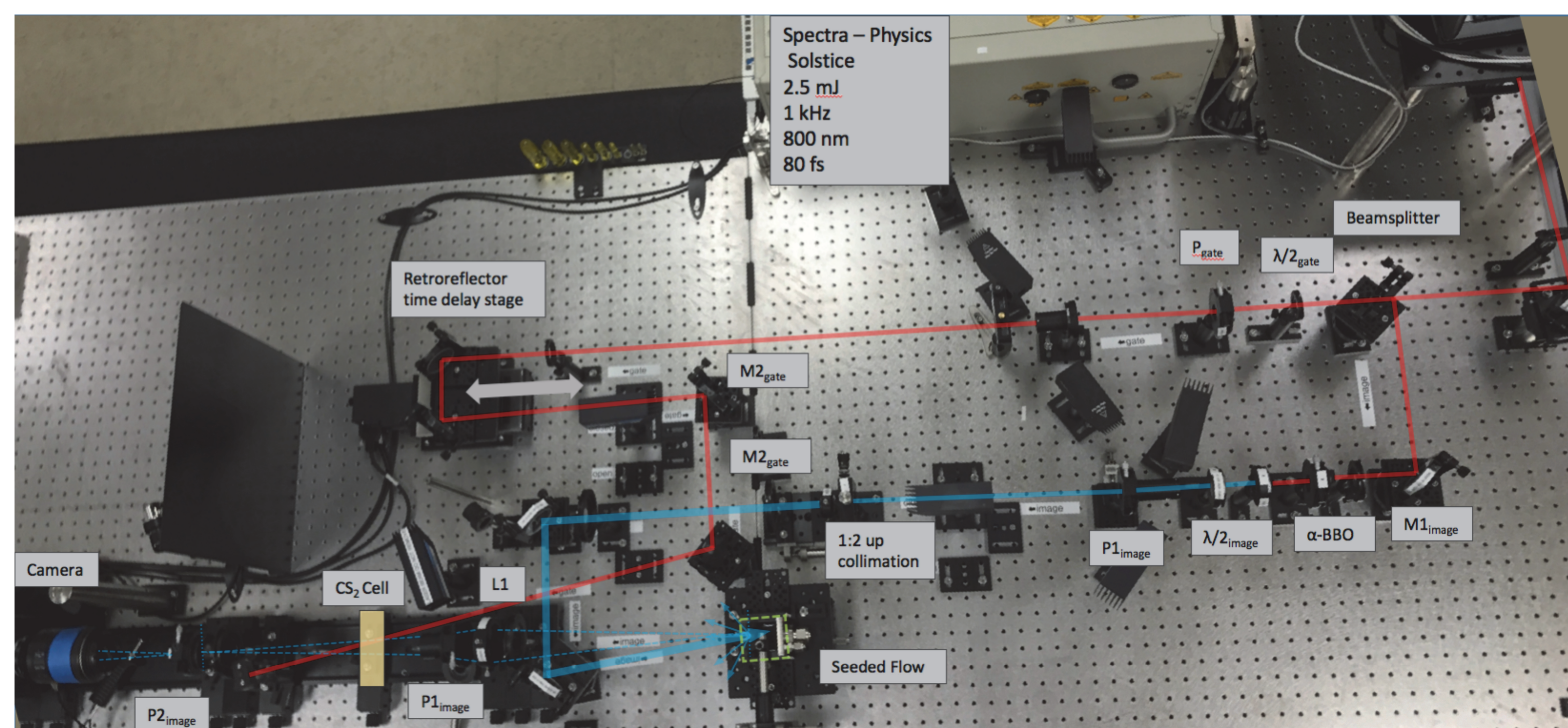
Motivation

- Particle Image Velocimetry (PIV) is well established but generally requires 2 or more optical access ports
- 2D flow measurements through a single optical port is desired for applications with limited access, such as in-cylinder
- Idea uses an ultrafast optical Kerr effect (OKE) shutter to achieve nearly planar imaging of backscattered illumination



Methodology

- Rahm's [1] time-gated optical sectioning applied to PIV
 - Ultrafast (~80 fs) pulses illuminate a particle seeded flow
 - Backscattered light (400 nm) sectioned using an ultrafast Optical Kerr effect (OKE) shutter
- High speed camera (Phantom v9.1) and intensifier (LaVision IRO) capture images at 1 kHz in sync with fs laser
- Time resolved vector field determined with LaVision PIV software

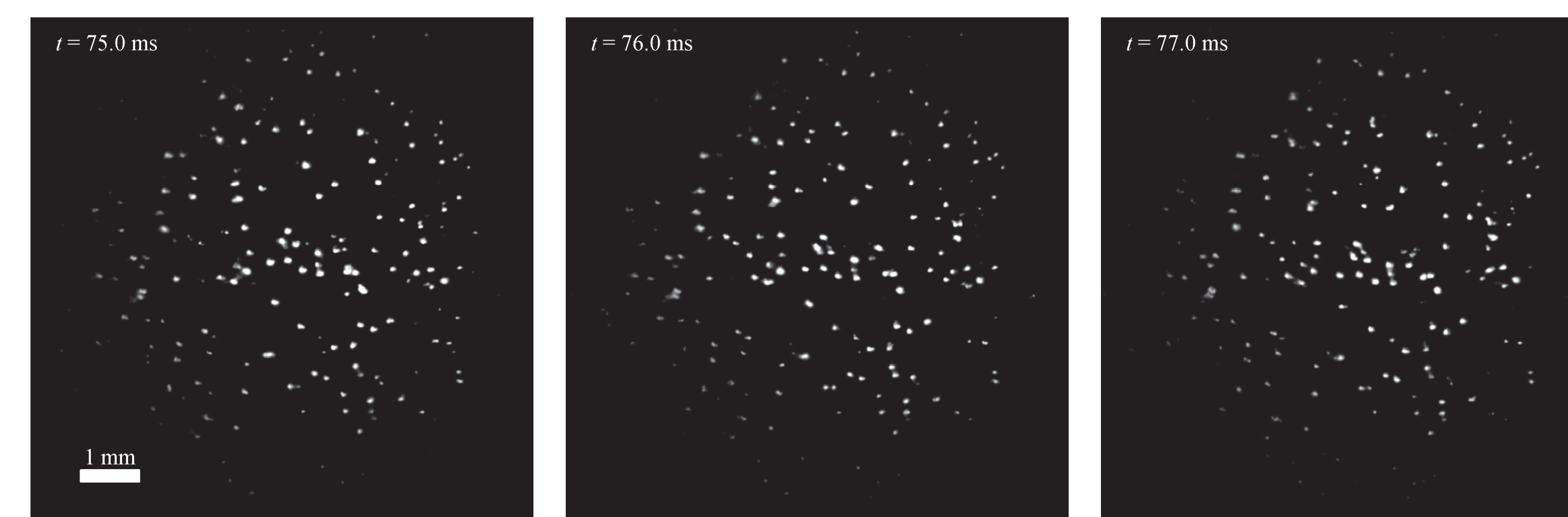


Conclusions

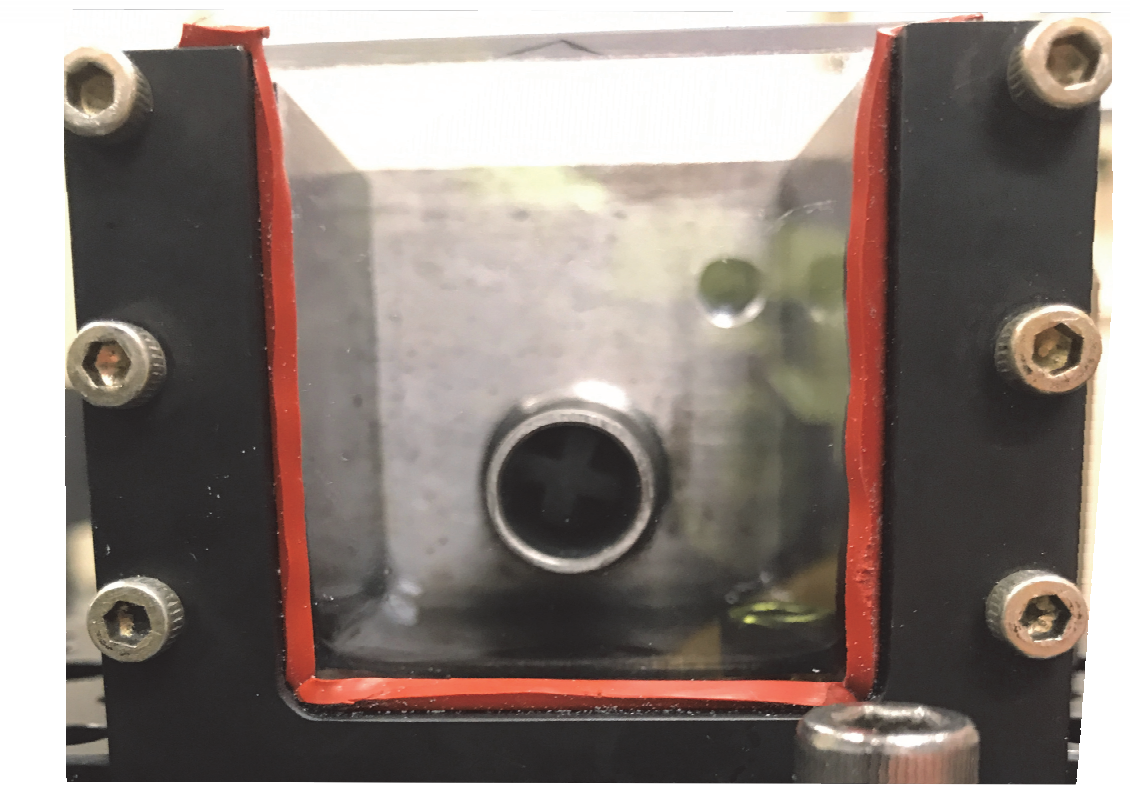
- PIVOTS is a novel method to achieve 2D velocimetry in flows with limited optical access
- Proof of concept results demonstrate flow resolution similar to conventional PIV
- Optical depth of the effective measurement volume is determined by the transmission time of the OKE shutter

Experimental Demonstration

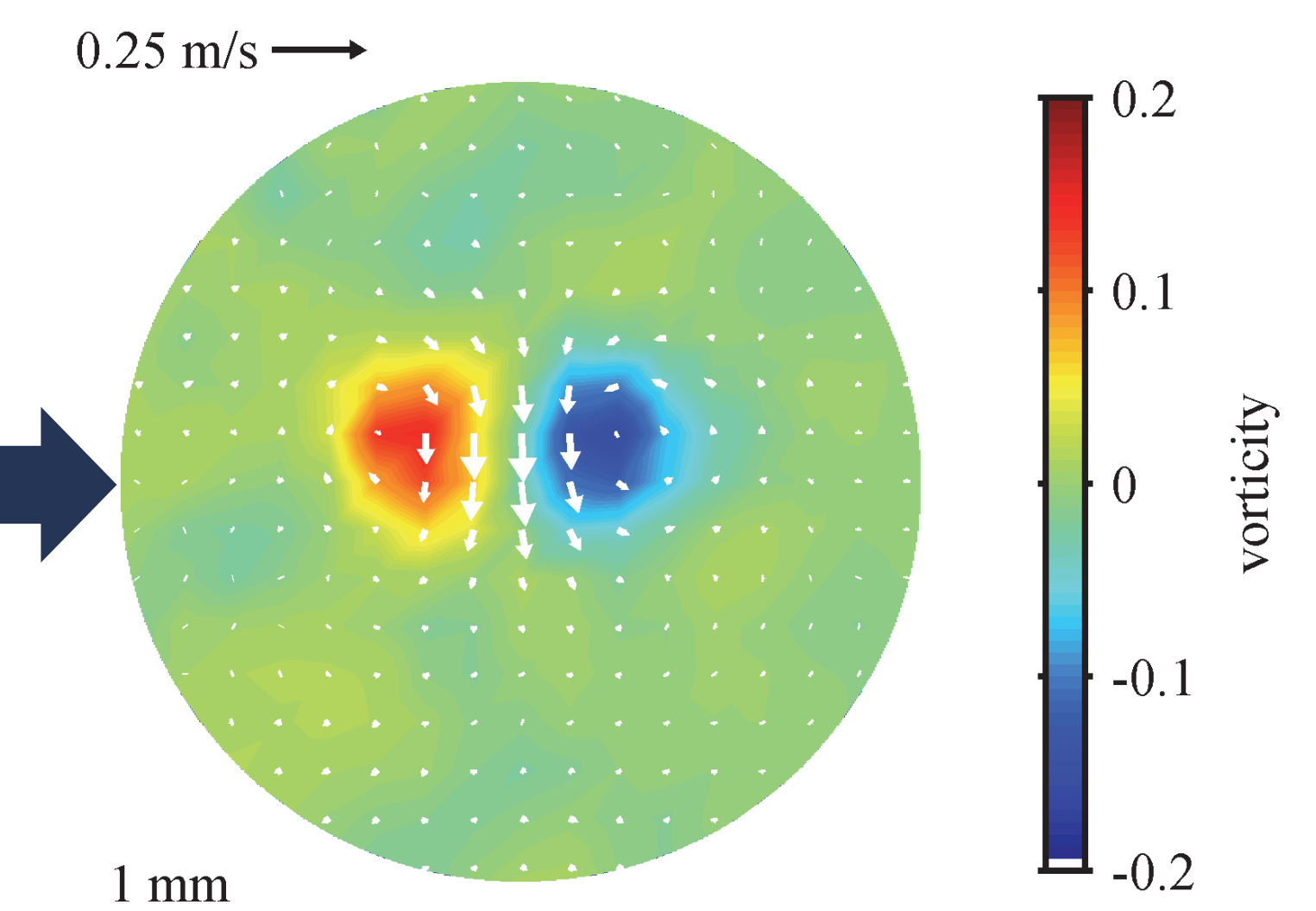
- Flow cell containing a single optical window
- First demonstration considers a pulsed vortex
 - OKE sectioned backscatter images are easily processed with cross-correlation methods to obtain velocity vectors
 - Imaging without OKE (not shown) yields no results



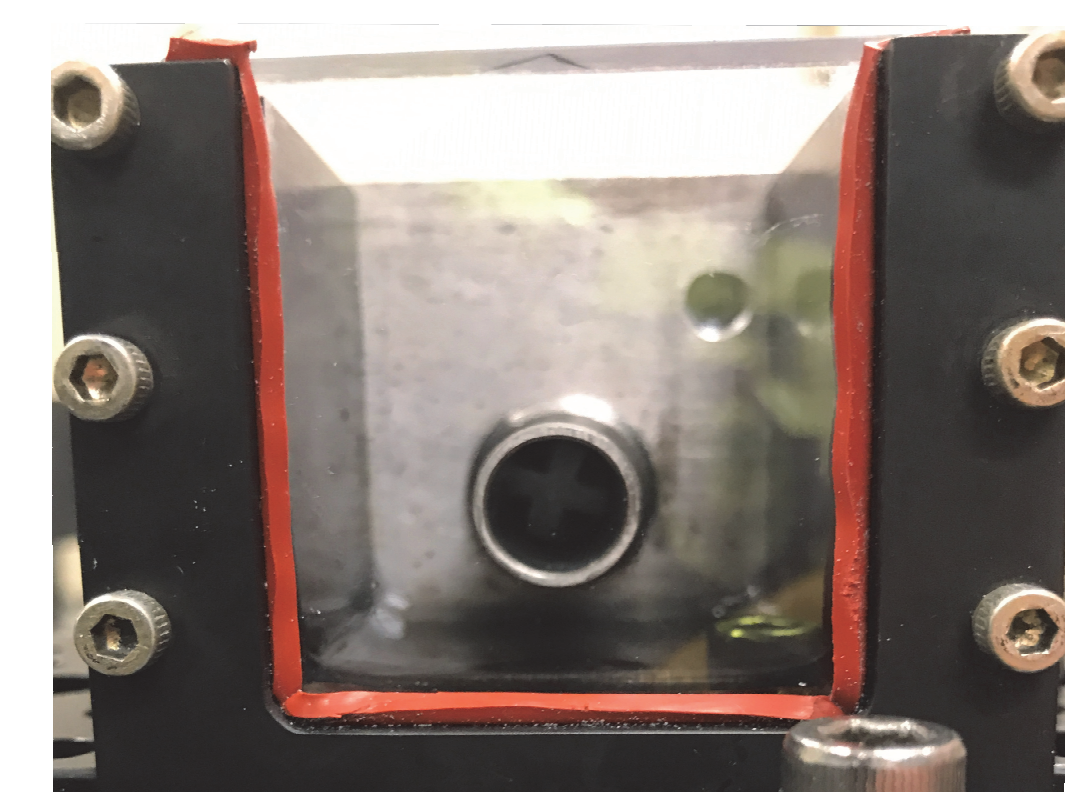
Time-resolved PIVOTS images of the pulsed vortex



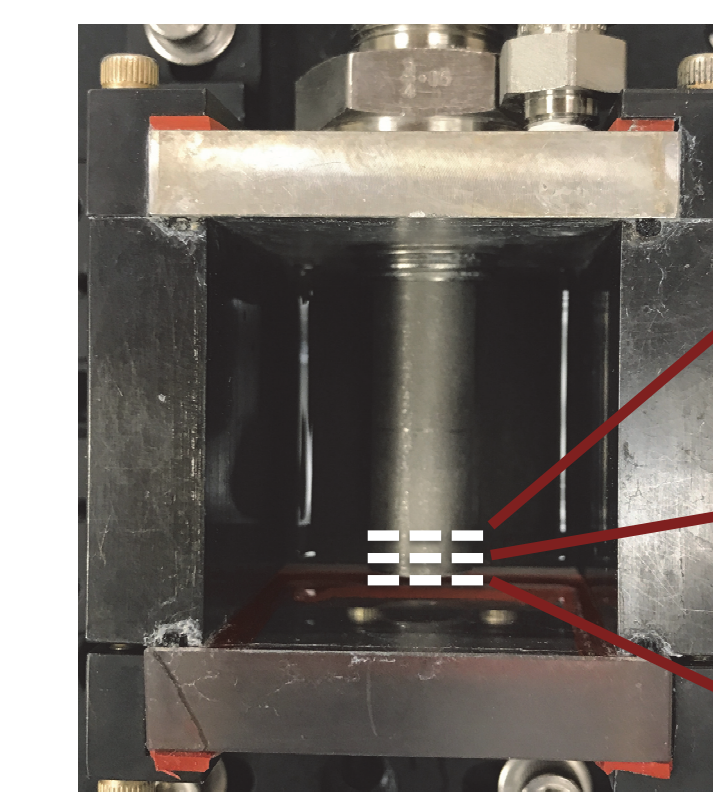
Flow cell containing water and 100 μm particles



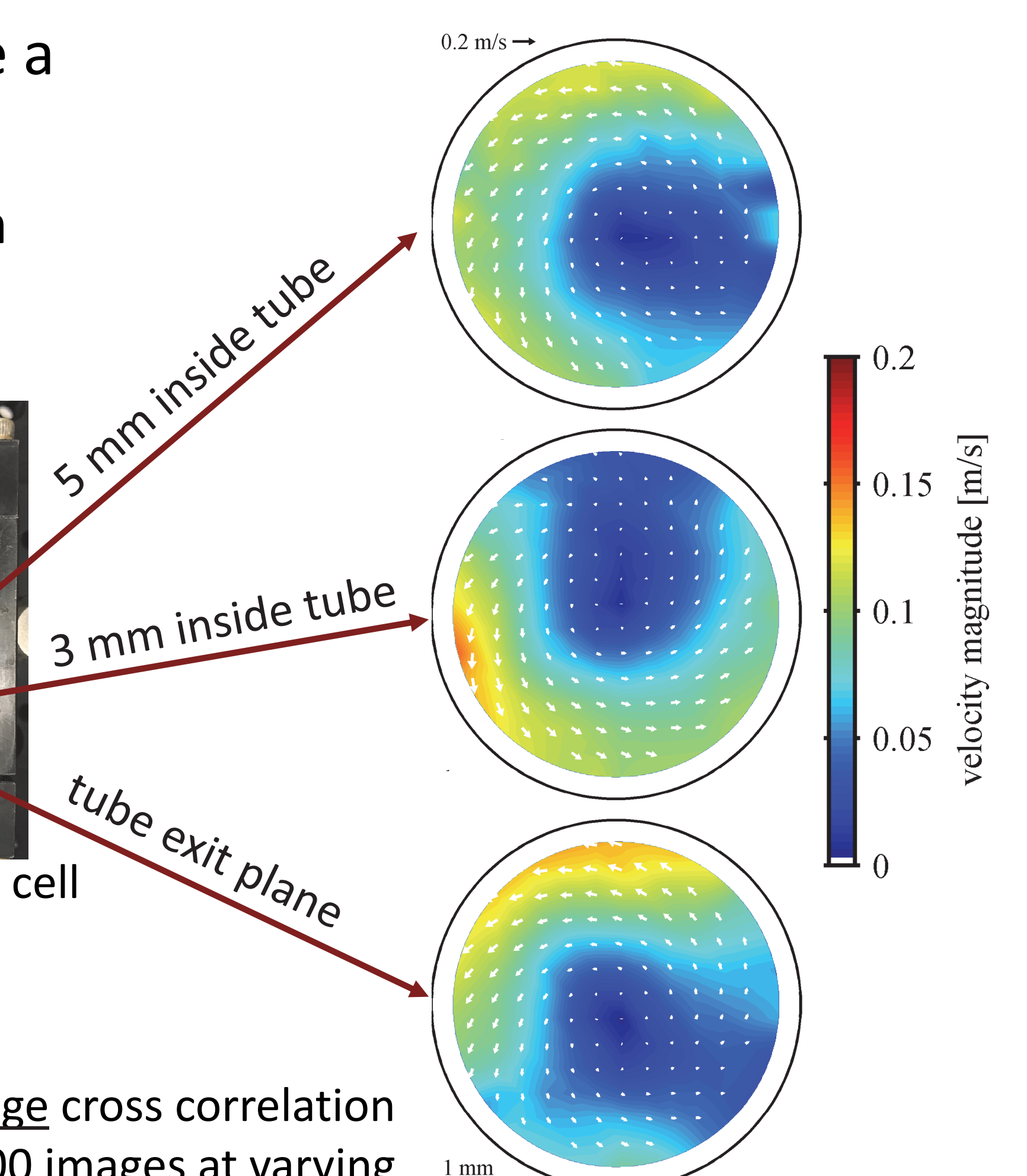
- Second demonstration considers swirling flow inside a stainless steel tube
 - PIVOTS enables measurement in a configuration with insufficient optical access for traditional PIV



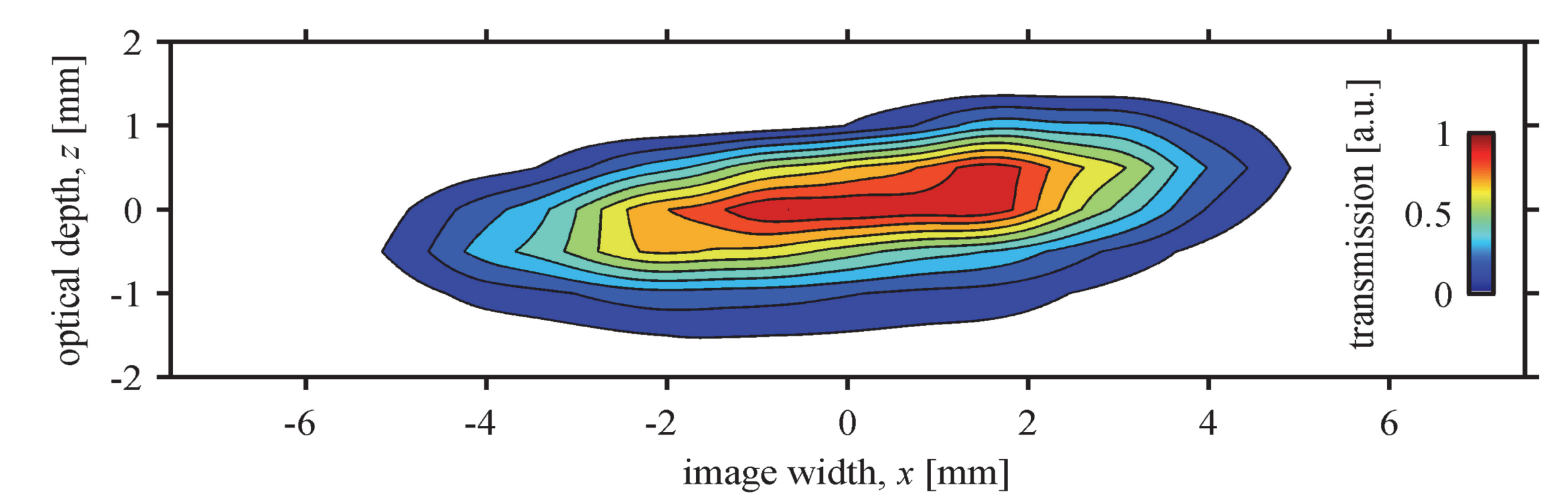
Looking down nozzle of flow cell



Top down view of flow cell



Average cross correlation results of 900 images at varying depths inside the nozzle



top view of the measurement volume determined by the OKE gate

Verification of effective measurement volume

- Backscattered intensity quantified by traversing a diffuse surface along the optical depth direction
- Effective measurement volume resembles a thin sheet common to PIV
- FWHM in z (~1.2 mm) is well correlated with OKE gate duration (~4 ps)

Possible Improvements

- S/N may be dramatically improved with a camera and intensifier better suited to the imaging wavelength
- An in-line configuration between gating and imaging beam could eliminate tilt in measurement volume
- Optical system should be optimized to match the depth of field determined by the OKE gate

References

- [1] M. Rahm, Z. Falgout, David Sedarsky, and Mark Linne, *Opt. Express*, **24**, 4610 – 4621 (2016).
- [2] R.J. Adrian, *Exp. in Fluids*, **39**, 159 - 169 (2005).
- [3] M. E. Paciaroni, Y. Chen, K. Lynch, and D. R. Guildenbecher, *in preparation* (2017).