

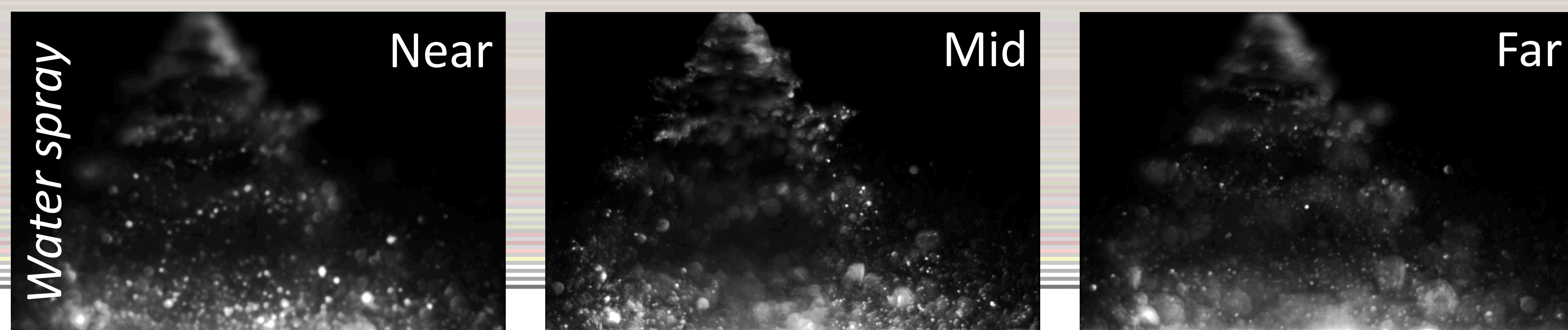
Recent advancements in particle tracking using 3D plenoptic diagnostics

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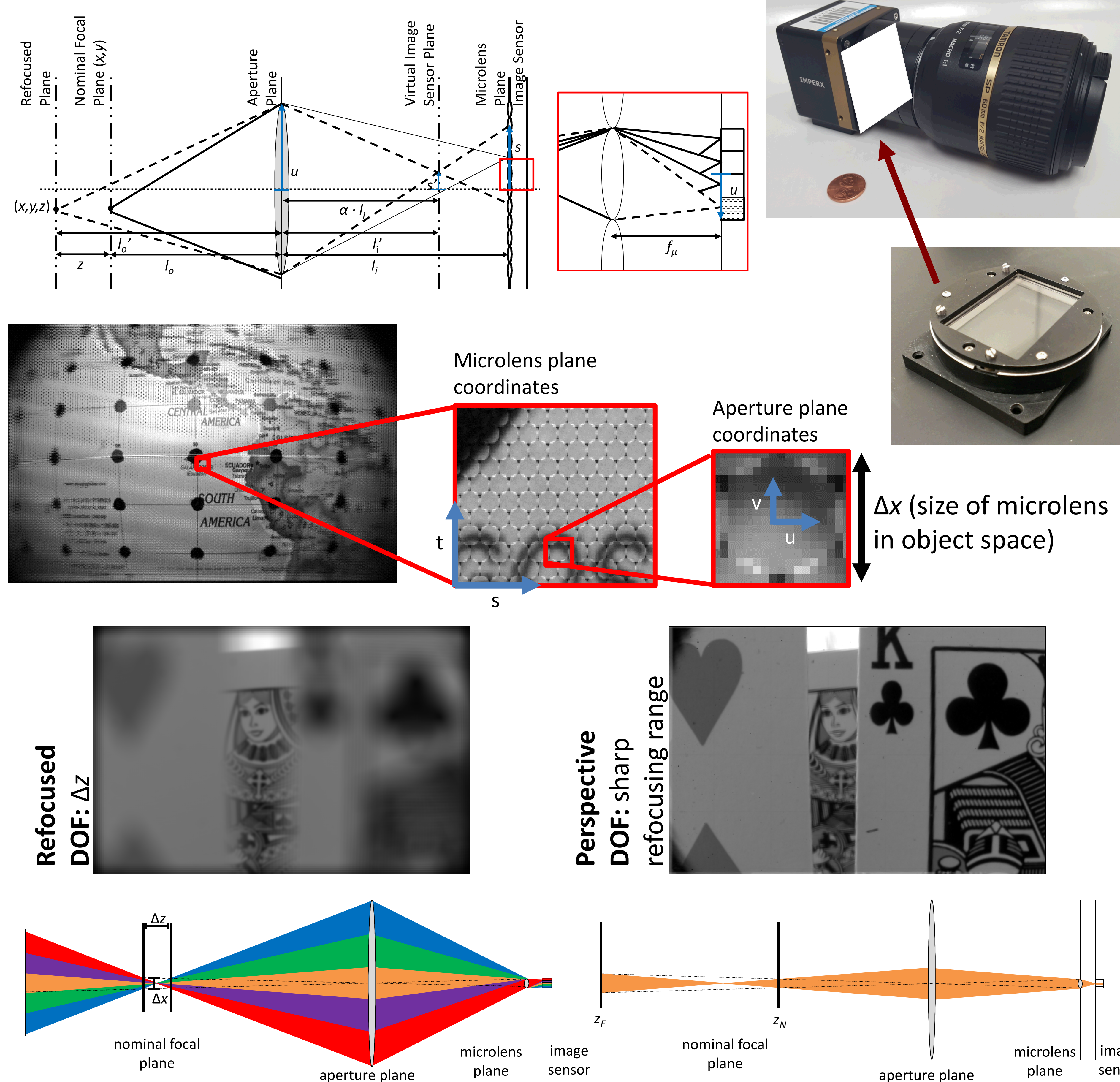
Diagnostic development goals

- Simple, single-camera 3D particle diagnostics
- Optimized data processing for plenoptic particle tracking with detailed understanding of measurement accuracy
- Uncertainty characterized via well controlled experiments



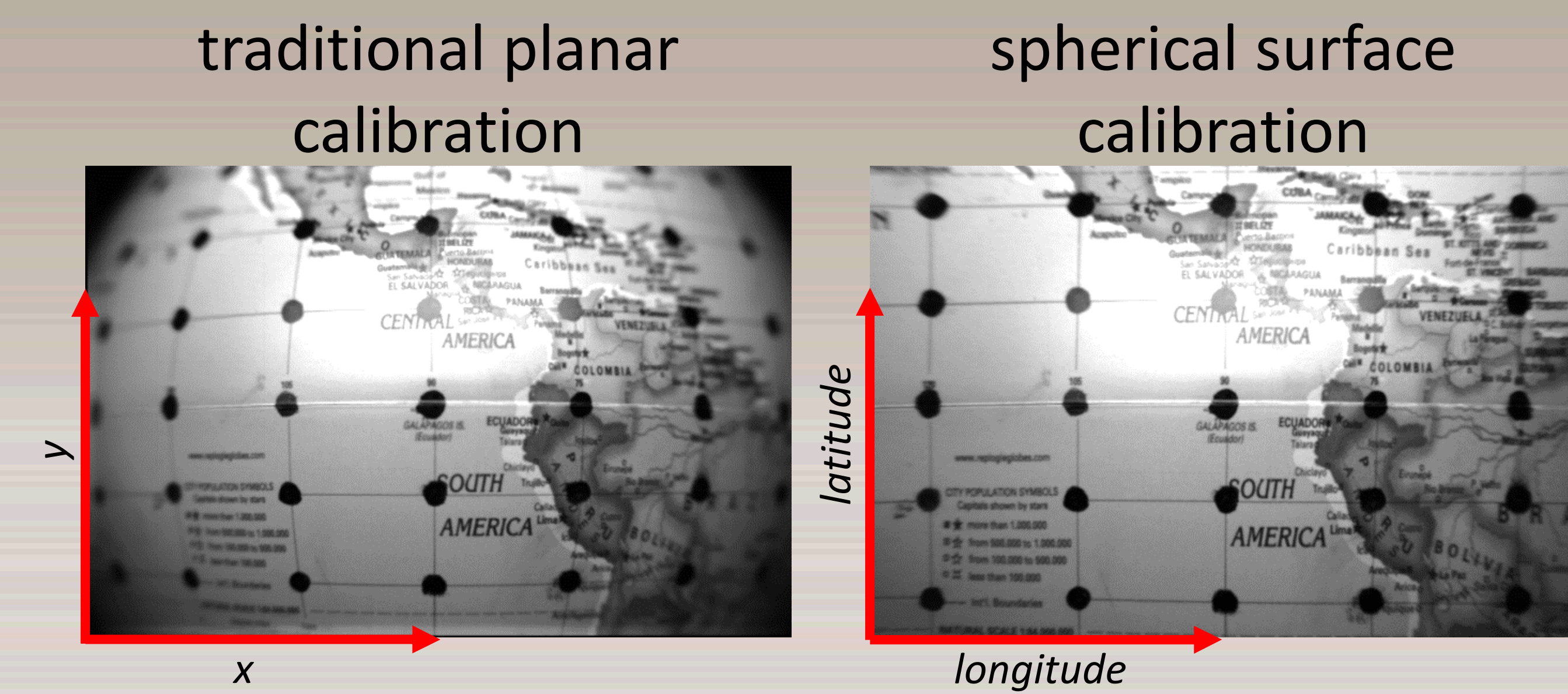
Plenoptic imaging [1]

- Micro lens array between the main objective and image sensor collects angular and spatial information in a single snapshot
- Post processing enables refocusing and changes in perspective
- Applications: consumer imaging, wind tunnel experiments, multiphase sprays, medical imaging, natural flow analysis



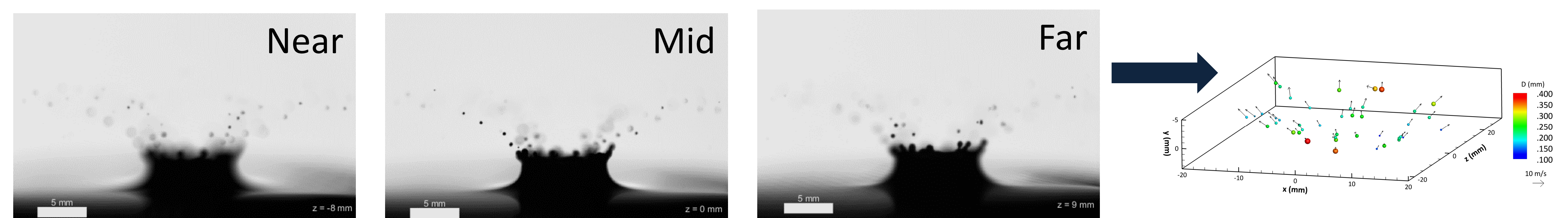
Volumetric calibration [2]

- Developed calibration techniques specific to the light-field equations
- Allows imaging of arbitrarily shaped surfaces
- Potential applications: flow phenomena near a curved wall, imaging symmetry surfaces



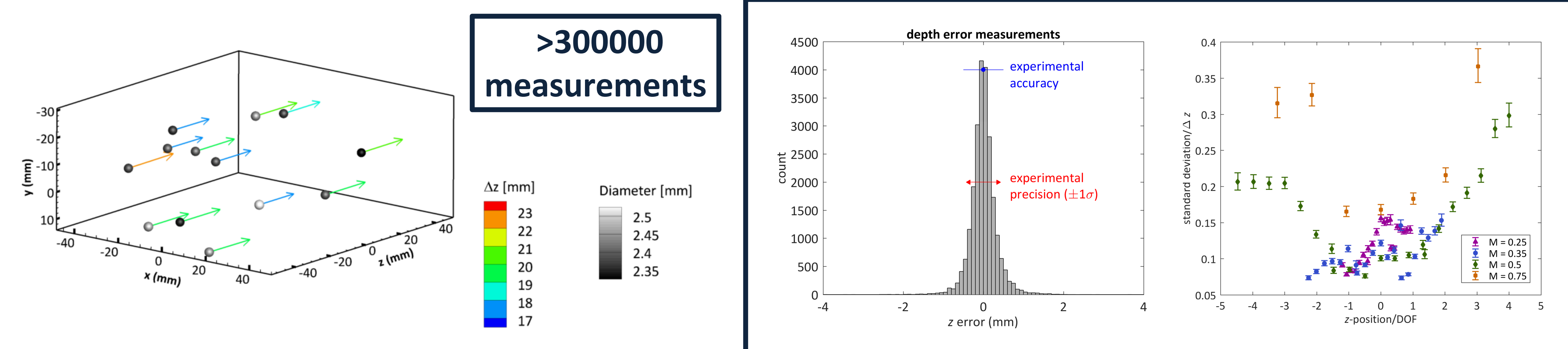
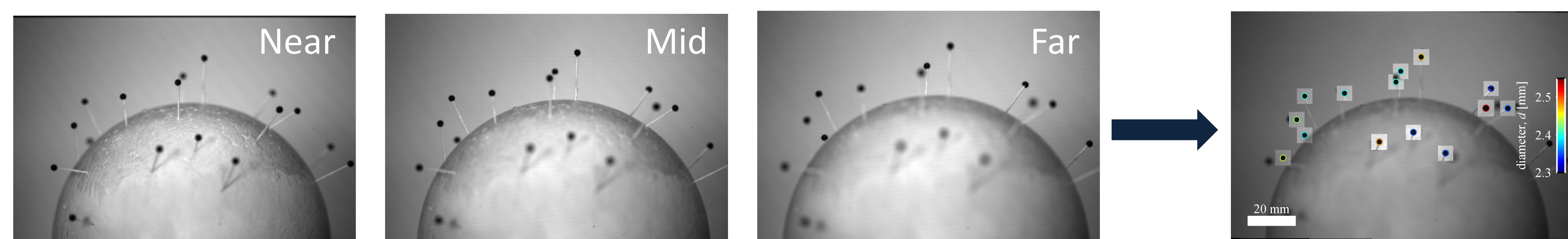
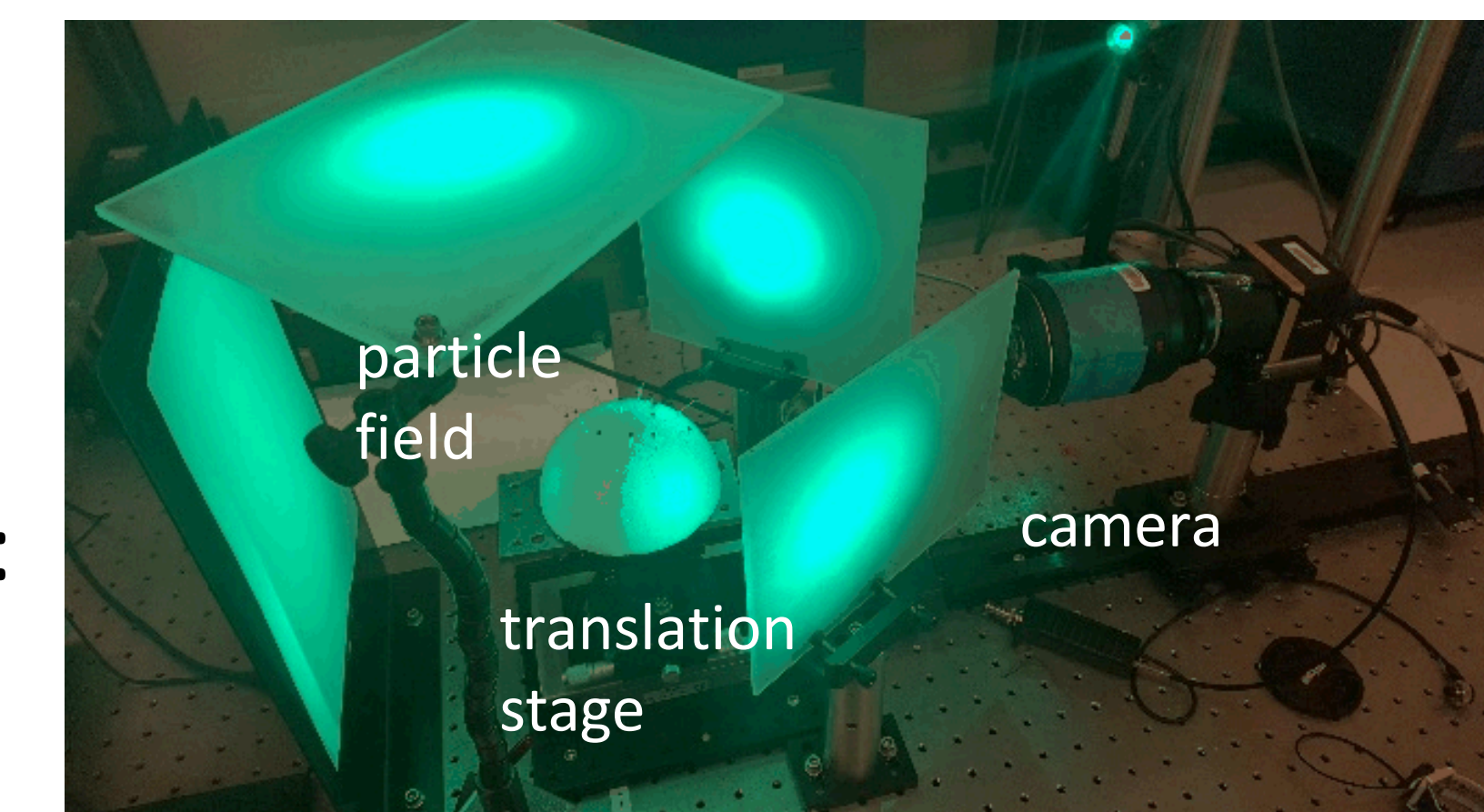
Drop impact application [3]

- Quantified 3D position/velocity of secondary droplets from two images in quick succession
- Measured trends are similar to previous DIH work
- Out-of-plane uncertainty ~ 1 mean particle diameter based on deviation from flow symmetry



Experimental uncertainty quantification [4]

- Well defined 3D 'particle' field for uncertainty quantification
- Large, statistically converged dataset
- Experimental uncertainty shown to agree with theoretical limits [5]:
 - Measurement domain bounded by DOF of perspective image
 - Precision limited by DOF of a refocused image



Magnification	l_o (mm)	DOF (mm)	Δz (mm)	Δx (μm)
0.25	525	140.4	10.7	308
0.35	405	70.9	5.4	220
0.5	315	34.6	2.6	154
0.75	245	15.3	1.2	103

Precision

- Depth $\sim 0.125 \Delta z$
- In-plane $\sim 0.2 \Delta x$

Accuracy

- Depth $\sim 0.06 \Delta z$
- In-plane $\sim 0.05 \Delta x$

Conclusions/future work

- Plenoptic imaging \rightarrow simple, single-camera 3D particle diagnostics
- Uncertainty scales with predicted DOF and spatial resolution
- Higher uncertainty in depth direction due to limited angular aperture
- Next step: explore alternative data processing (e.g. position from perspective shift)

References

- [1] R. Ng, M. Levoy, G. Duval, M. Horowitz, and P. Hanrahan, Stanford Tech Rep. CTR 1-11 (2005).
- [2] E. M. Hall, T. W. Fahringer, and B. S. Thurow, AIAA SciTech Forum, 55th Annu. Aerosp. Sci. Meet. 1-13 (2017).
- [3] E. M. Hall, B. S. Thurow, and D. R. Guildenbecher, Appl. Opt. 55, 6410-20 (2016).
- [4] E. M. Hall, D. R. Guildenbecher, and B. S. Thurow, ILASS-Americas 29th Annual Conference on Liquid Atomization and Spray Systems, Atlanta, GA, (2017)
- [5] E. A. Deem, L. N. Cattafesta, T. W. Fahringer, and B. S. Thurow, Meas. Sci. Technol. 27, (2016).