SAND2023-05975C

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TOWARDS HIGH-SPEED DIGITAL HOLOGRAPHY THROUGH FIBER IMAGING BUNDLES

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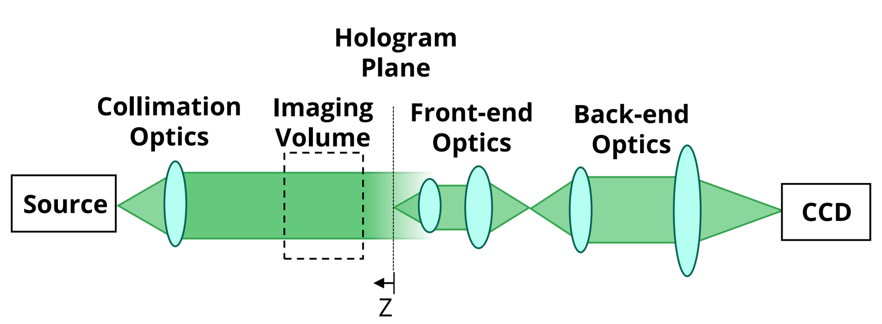
Diagnostic development goal

Digital holography is a useful tool for quantitative particle tracking within a 3D volume and has been applied to several combustion and energy applications. In many potential applications, the volume of interest is located within a harsh environment with limited optical access. Here we explore the use of coherent fiber imaging bundles for separating camera hardware from the action for high-speed fiber bundle digital holography (FBDH).

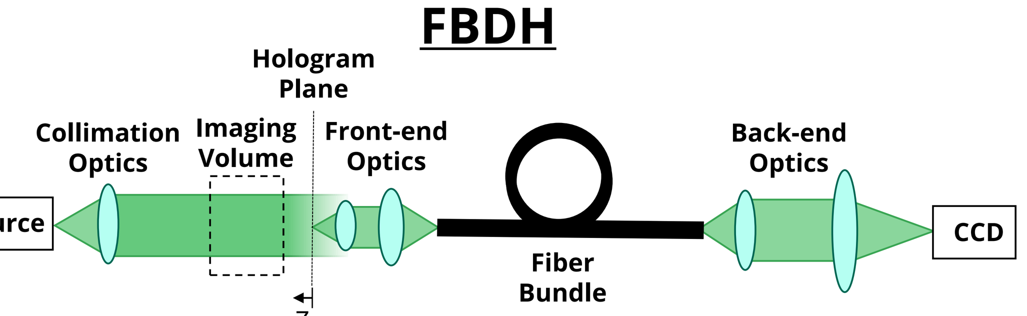
Examples of harsh environments for optical diagnostics [1]

Experimental configuration

Traditional DIH



FBDH

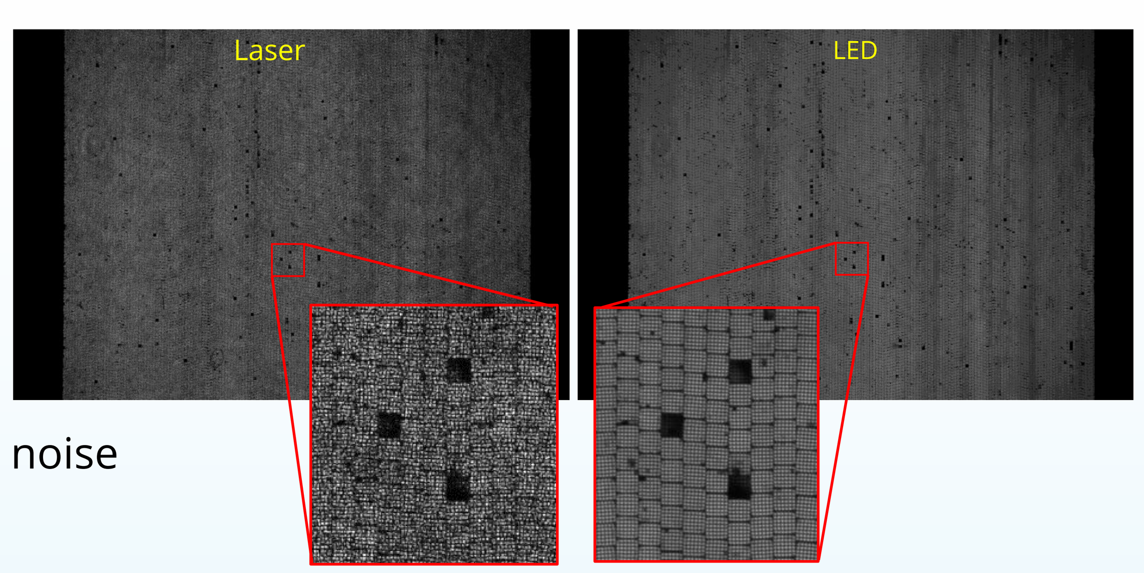


Imaging configuration

- Collimated source illuminates imaging volume
- Front-end optics magnify and relay hologram to face of fiber bundle
- Back-end optics image second face of fiber bundle onto detector
- For direct comparison to traditional digital in-line holography (DIH), the same optics are used with the fiber removed (Back-end optics relay intermediate image from front-end optics)

Fiber bundle

- Schott wound fiber imaging bundle
    - Aperture: 10 mm x 10 mm
    - 6x6 arrays of 10 um fibers
    - ~10^6 fibers
    - Resolution ~45 lp/mm
- Multimode fibers introduce significant speckle noise under coherent illumination



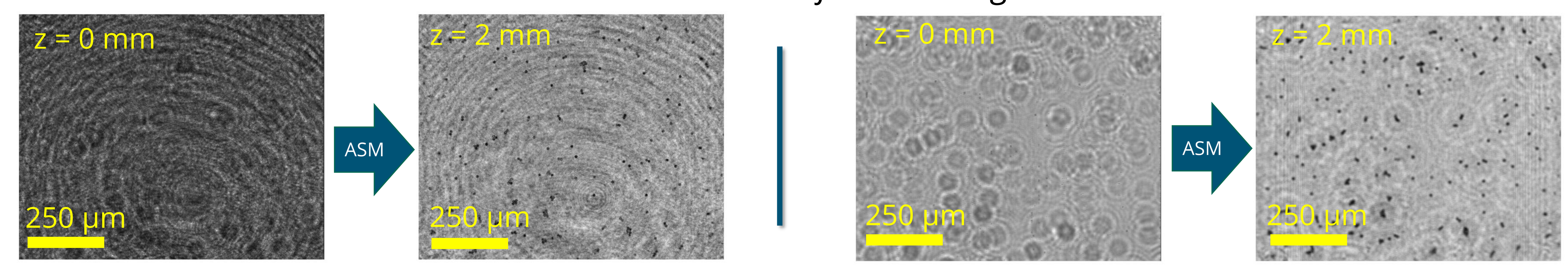
Transmission of collimated laser and LED sources through fiber bundle

Illumination Sources

- Laser: 532 nm, CW Nd:YAG
- LED: 530 nm (30 nm FWHM) fiber coupled LED

Preliminary results

Numerical reconstruction of FBDH holograms

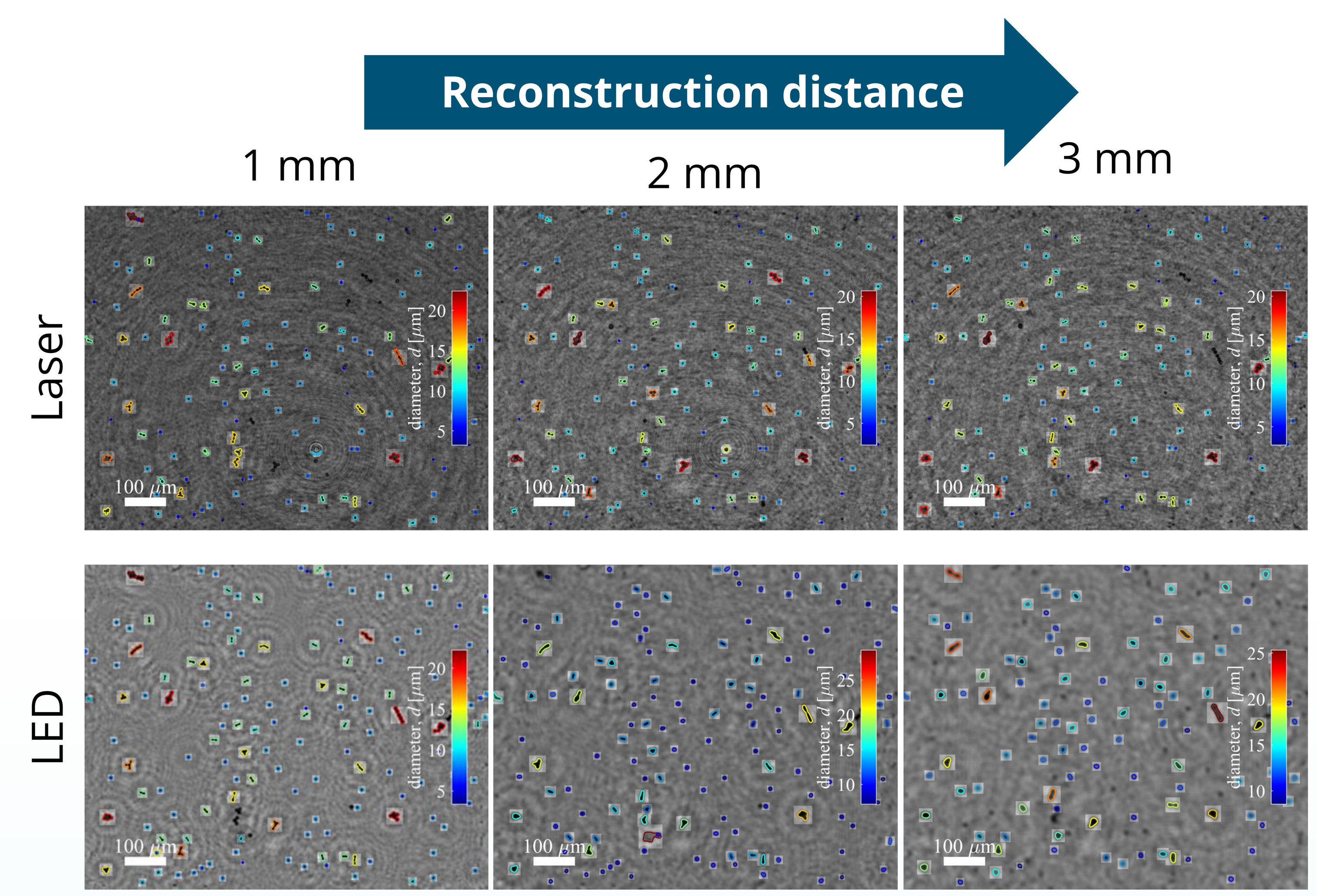


Laser illumination *LED illumination*

- Holograms recorded of SiO_2 microspheres (D = 9.2 μm) deposited on AR coated windows
- Numerical propagation and reconstruction using the Angular Spectrum Method (ASM) [2]
- LED source reduces speckle noise but limits numerical propagation distance

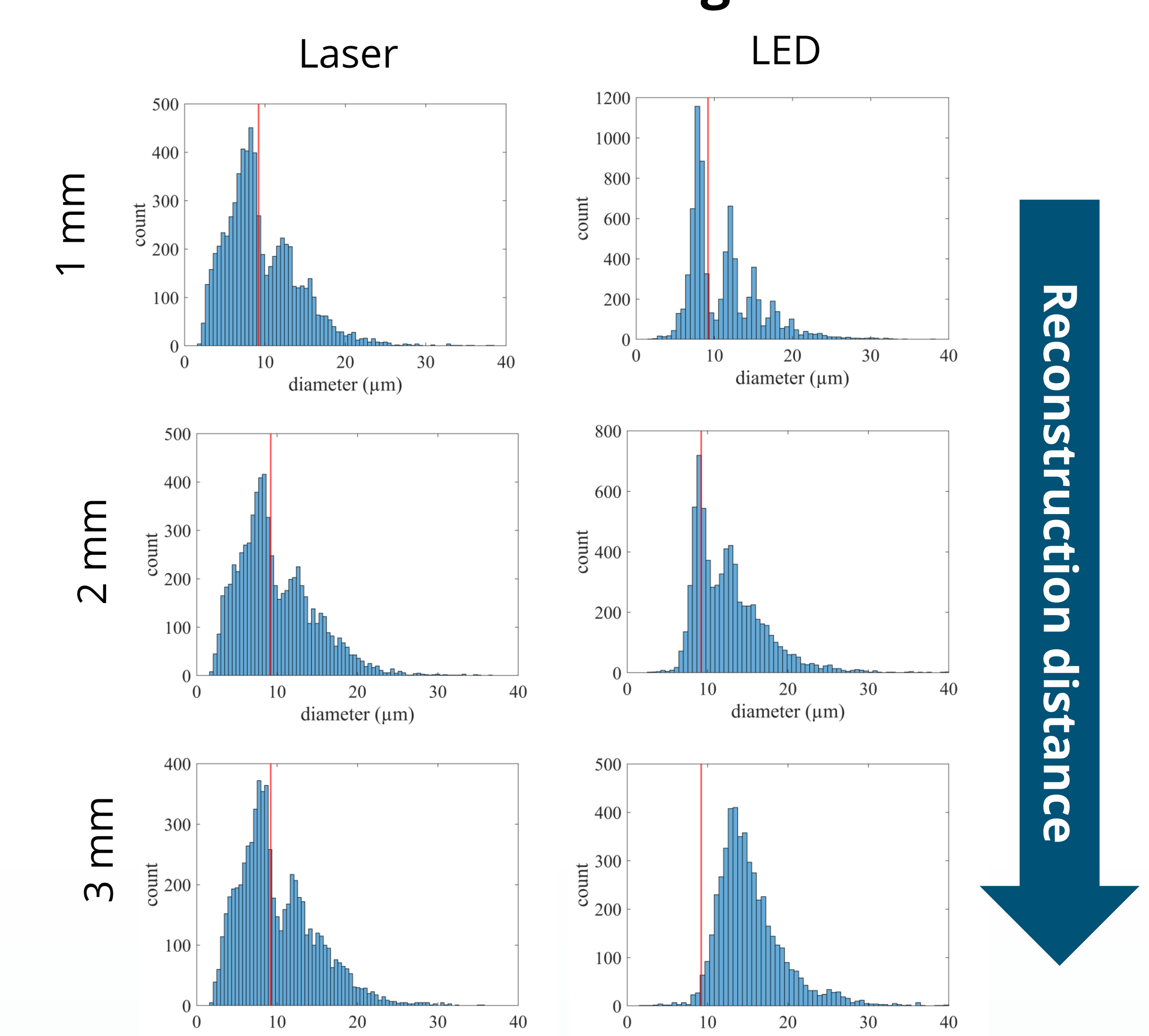
Particle sizing

- Holograms recorded at 1 mm, 2mm, and 3 mm over 50 similar ROI
- Automated particle detection by thresholding minimum phase angle [3]



Particle detection for numerically reconstruction of FBDH holograms for 1 mm, 2mm, and 3 mm propagation distances under laser and LED illumination

Particle sizing



Distributions of effective diameters of detected particles. Red line indicates nominal particle size (D = 9.2 μm)

Future direction

- Direct comparison with traditional DIH in free space
- Testing on dynamic system using picosecond laser to freeze motion, while controlling source coherence using nonlinear optical components

References

1. Guildenbecher, D.R. "Optical Diagnostics for Explosive Fragmentation and Fireballs." United States. 2019. https://www.osti.gov/servlets/purl/1640135.
2. Goodman, J. W., *Introduction to Fourier Optics*, 3rd ed., Roberts & Co., Greenwood Village, 2005, pp. 31-60
3. Guildenbecher, D. R., Gao, J., Reu, P. L., and Chen, J., "Digital holography simulations and experiments to quantify the accuracy of 3D particle location and 2d Sizing using a proposed hybrid method," *Applied Optics*, vol. 52, 2013, p. 3790. doi: 10.1364/ao.52.00

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