A fast, non-iterative ray-intersection approach for three-dimensional microscale particle tracking

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Motivation

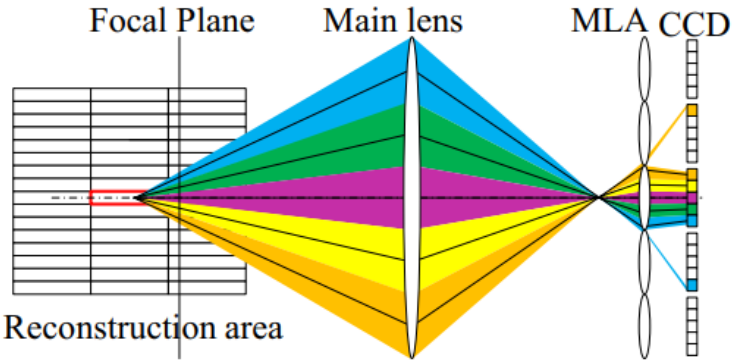
- Multi-Camera systems are not suitable for particle tracking in micro-scale domains due to limited space.

- Light field based algebraic algorithm(e.g. MART) usually require large memory (e.g., ~200GB for 10^7 voxels) to store the weight matrix and high computation power for 3D reconstruction.

- For 3D micro PIV, the particle concentration is usually low. We provide a broader and faster approach for sparse particle reconstruction with robust calibration.

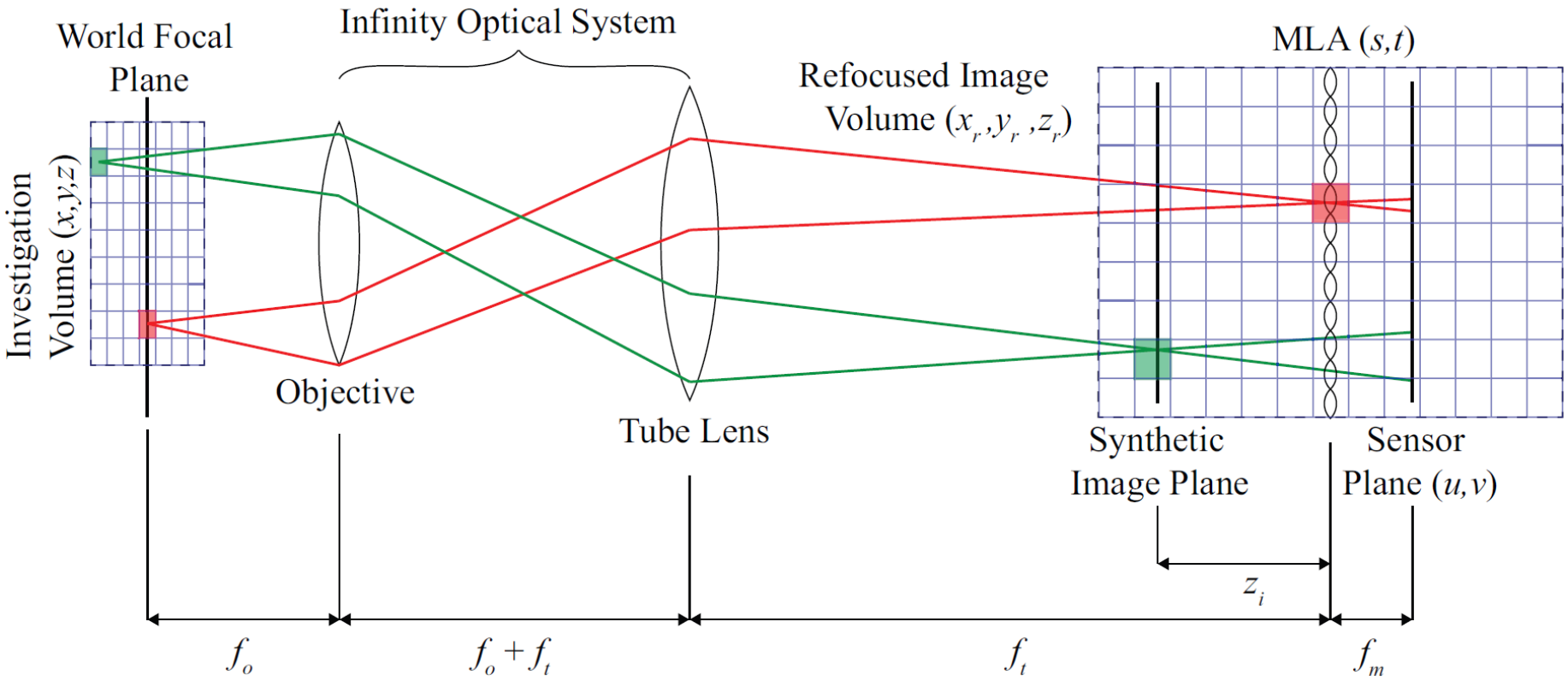
$$I(x_i, y_i) = \sum_{j \in N_i} W_{i,j} E(X_j, Y_j, Z_j)$$

$$E_j^{k+1} = E_j^k + \mu \frac{\sum_i \left(\frac{I_i - \sum_{n=1}^{N} W_{in} E_n^k}{\sum_{n=1}^{N} W_{in}} \right) W_{i,j}}{\sum_i W_{i,j}}$$



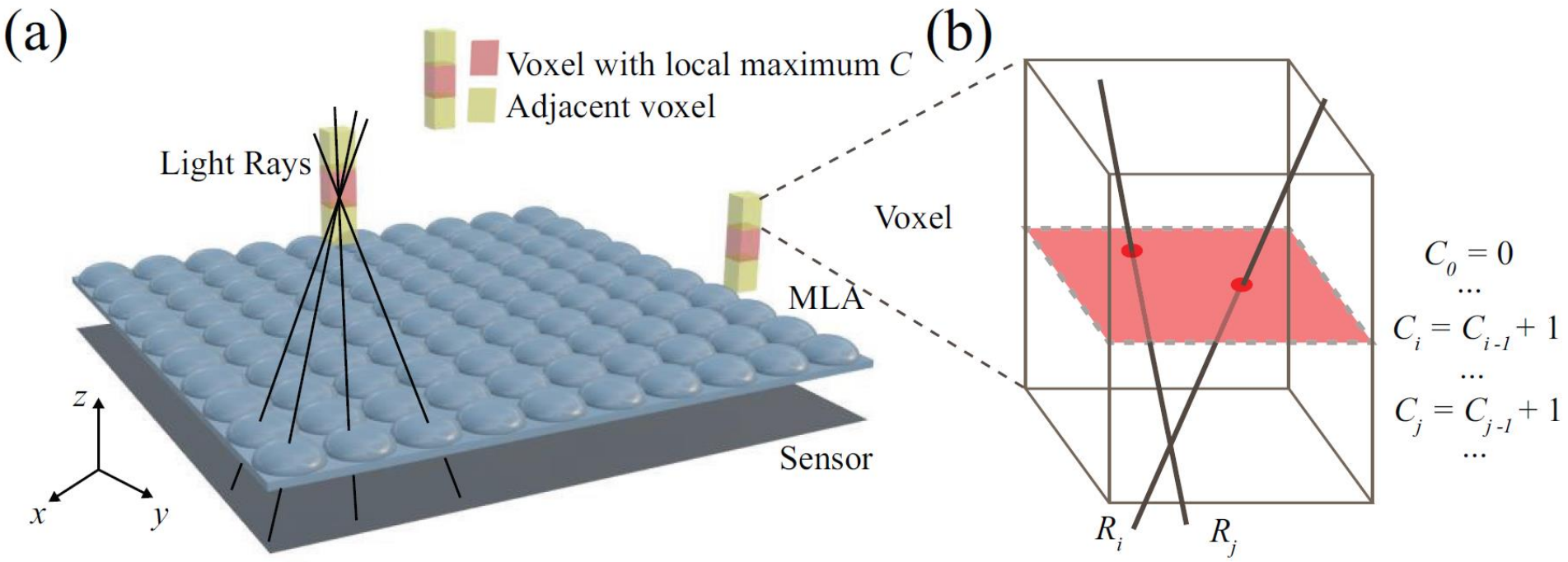
Shi, Shengxian, et al, *experiments in Fluids* 58, no. 7 (2017): 1-16.

Light filed microscope



Light field system with an infinity-corrected microscope.

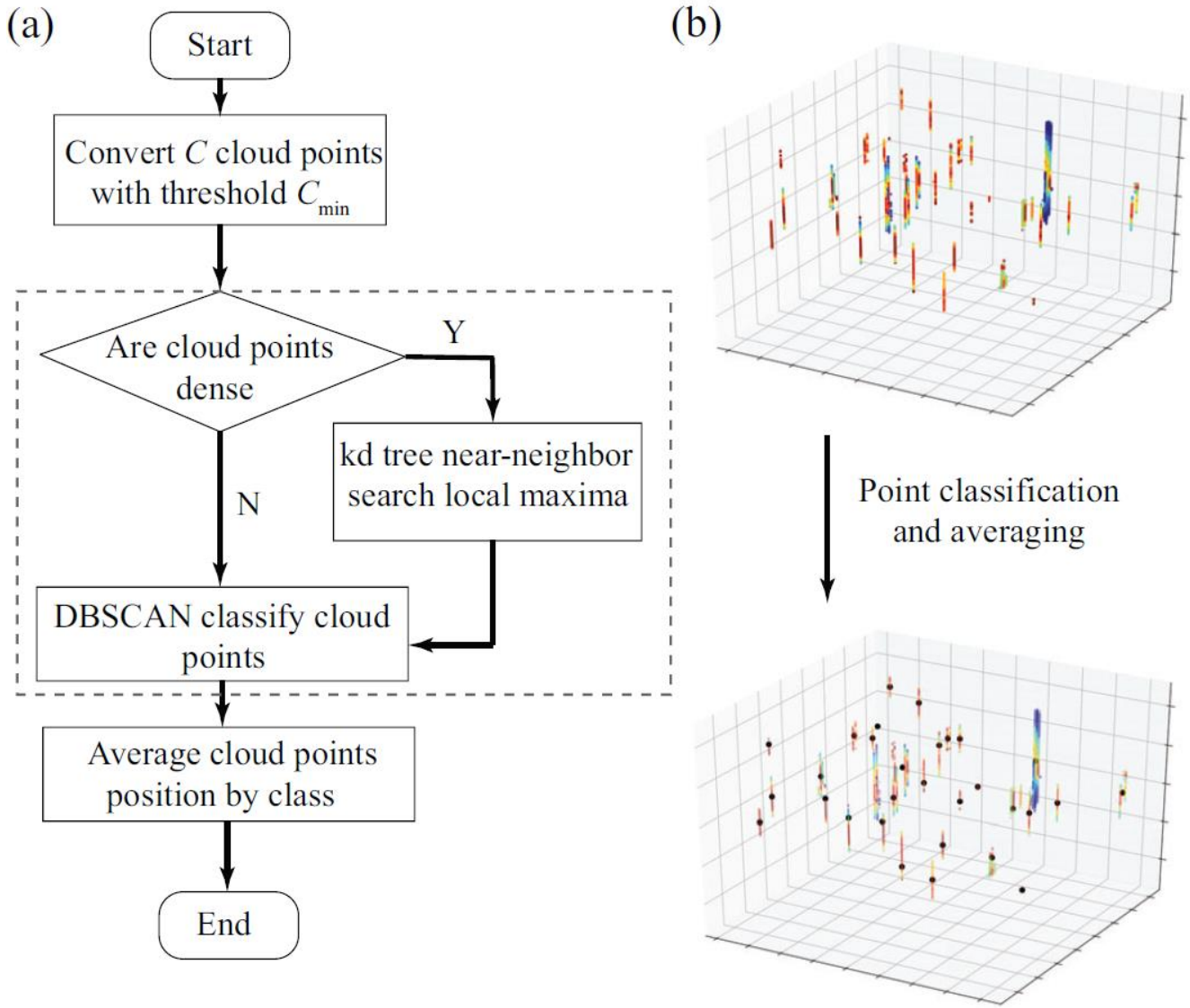
Reconstruction algorithm



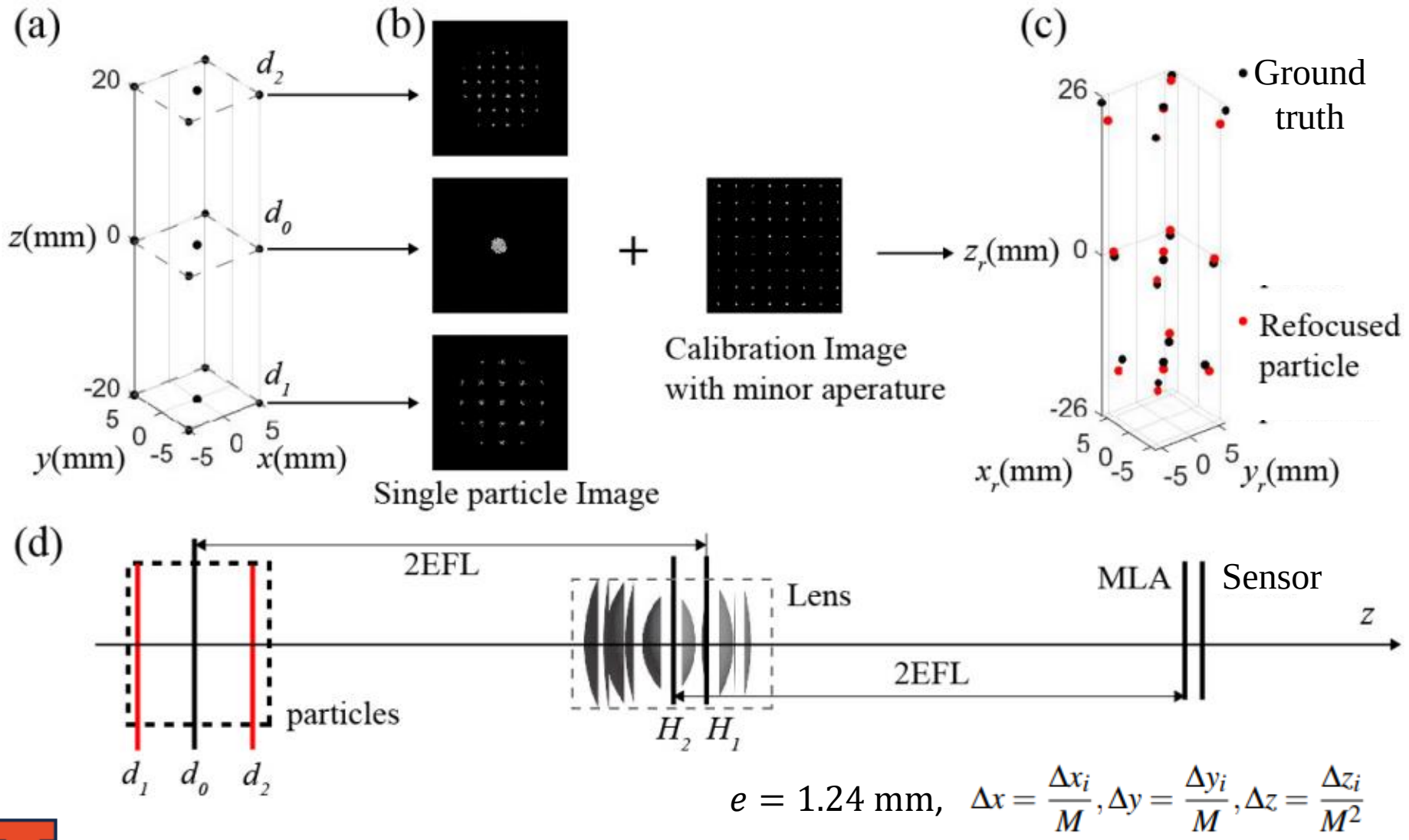
3D light ray diagram around MLA.

Increment of ray counter in one voxel.

Cloud point classification

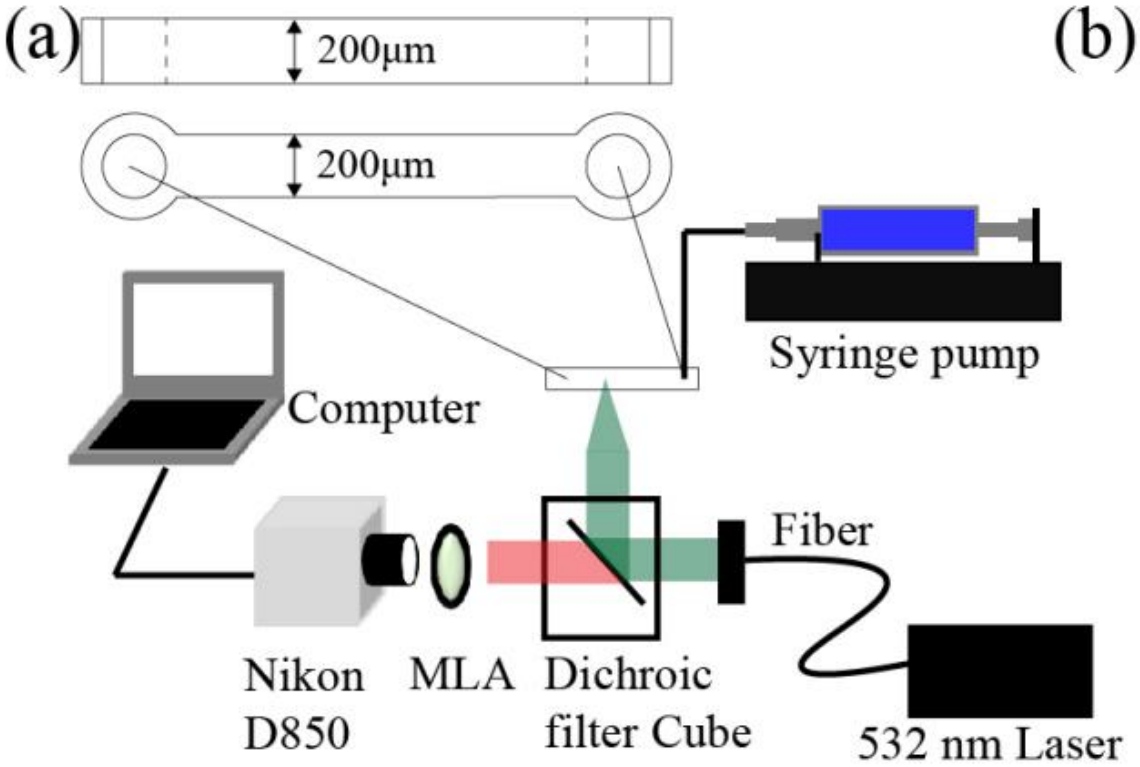


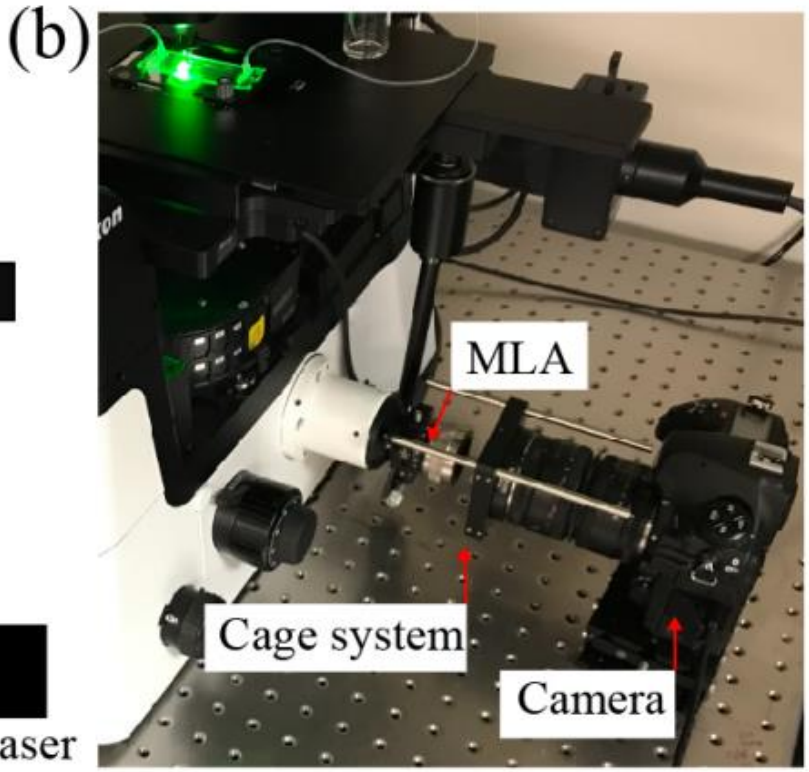
Simulation



$e = 1.24$ mm, $\Delta x = \frac{\Delta x_i}{M}, \Delta y = \frac{\Delta y_i}{M}, \Delta z = \frac{\Delta z_i}{M^2}$

Experimental setup





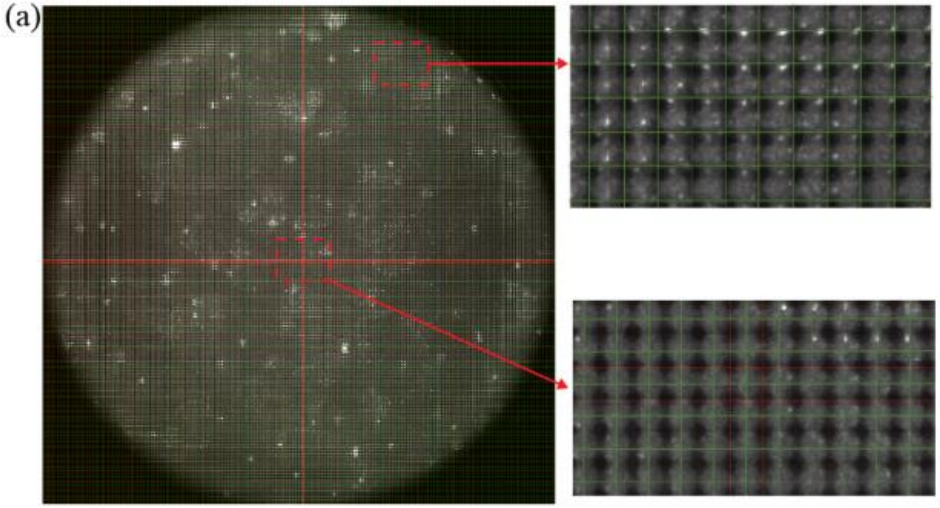
(a) Schematic of experiment setup

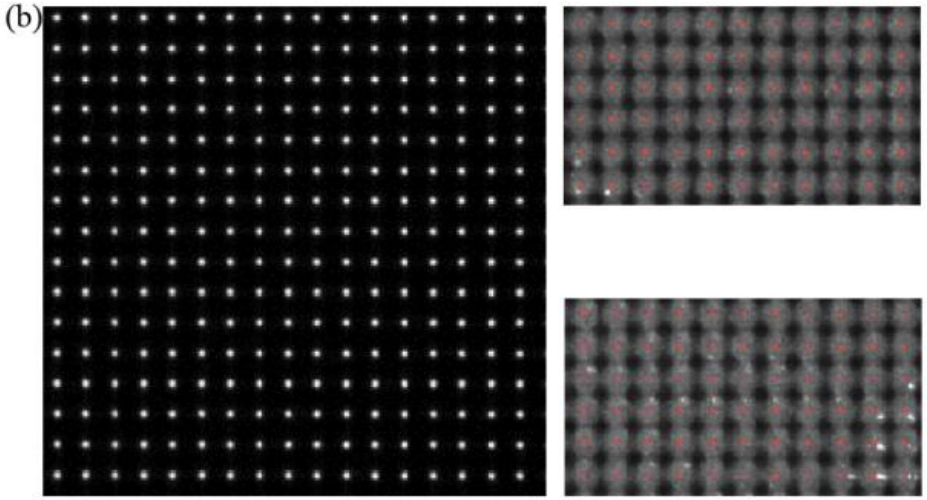
(b) MLA cage system with 1:1 DSLR Camera

- 1.7-2.2 µm fluorescent particles
- 0.85 µl/min flow rate

- 7 hz sampling frequency
- 9.6 µm depth resolution

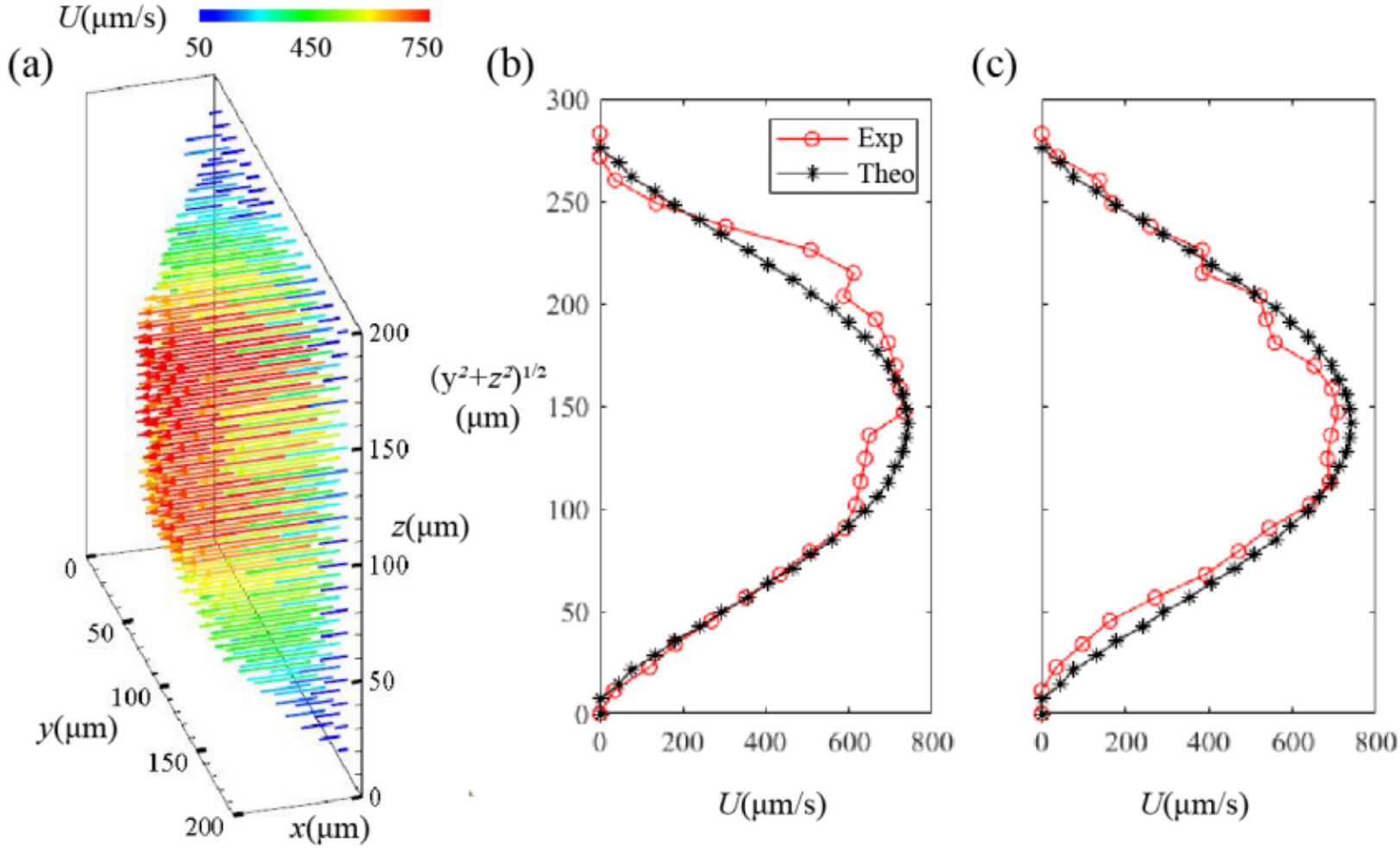
Calibration





- Misalignment happens with uniform grid.
- Lenslet center detection via blob detection of calibration image with small condenser aperture

3D flow profile



(a) A view of the velocity distribution.

(b) Velocity profile along the y − z diagonal direction; (c) the other diagonal.

Remarks

- We developed non-iterative fast method for sparse particle reconstruction and tracking with microscope.
- Ray simulation was performed to inspect uncertainty of reconstruction algorithm; it resulted low in objective space.
- We designed a calibrated optical cage system and evaluated the performance of the proposed algorithm in a fully-developed, laminar flow.