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TRANSPORT OF FIBERS IN STRUCTURED MEDIA: TOWARD A SORTING DEVICE

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1. OBJECTIVES

We experimentally and numerically study the transport of fibers around rigid obstacles in a microfluidic channel. The objective is to characterize the dynamics and the trajectories of the fibers as a function of their mechanical and geometrical properties.

2. METHODS

Experimental setup

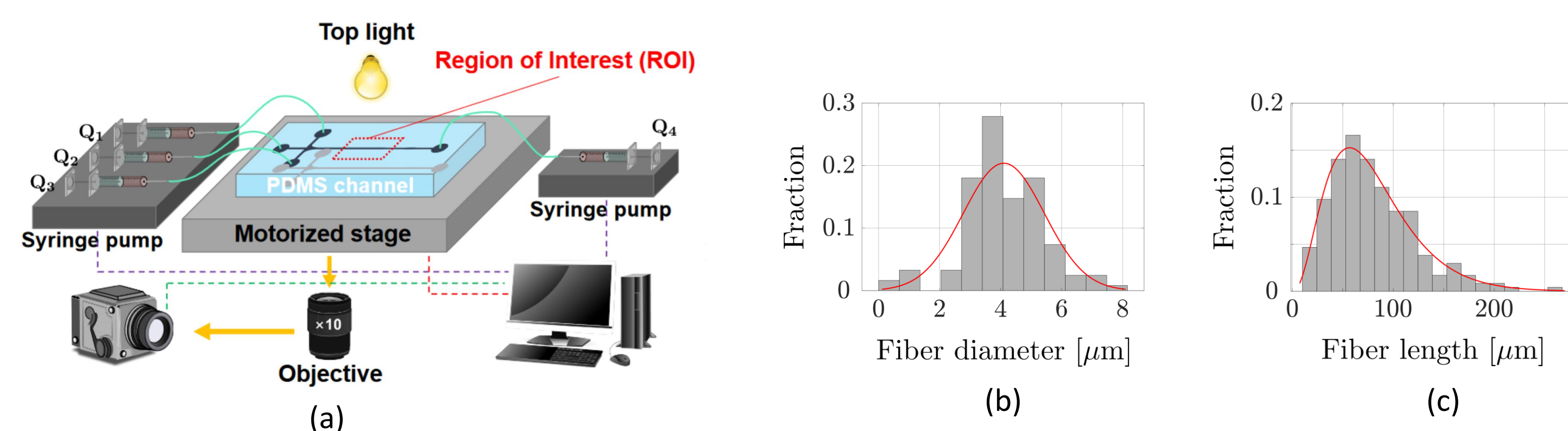


Figure 1. (a) Sketch of the experimental setup showing the microfluidic channel, the flow control and the data acquisition. (b) The distribution of the fiber width. (c) The distribution of the fiber length.

Numerical setup

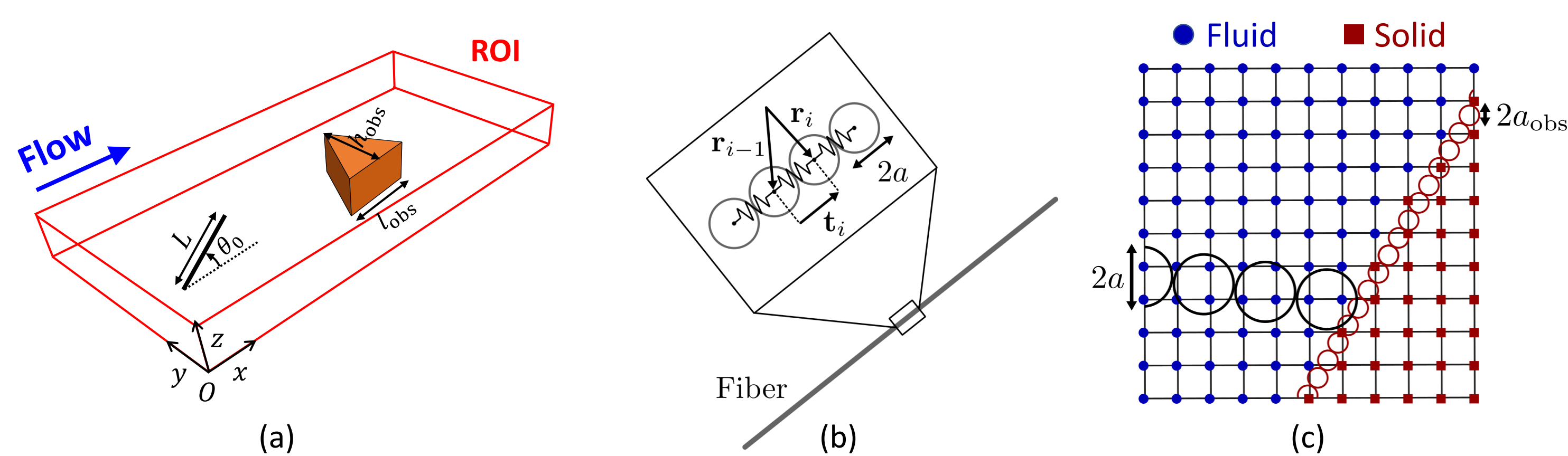


Figure 2. (a) Zoom on the region of interest. (b) Discretization of the fiber using spherical beads connected together by springs. (c) The Eulerian grid where the fiber and the obstacle are immersed.

Computation of the fiber dynamics

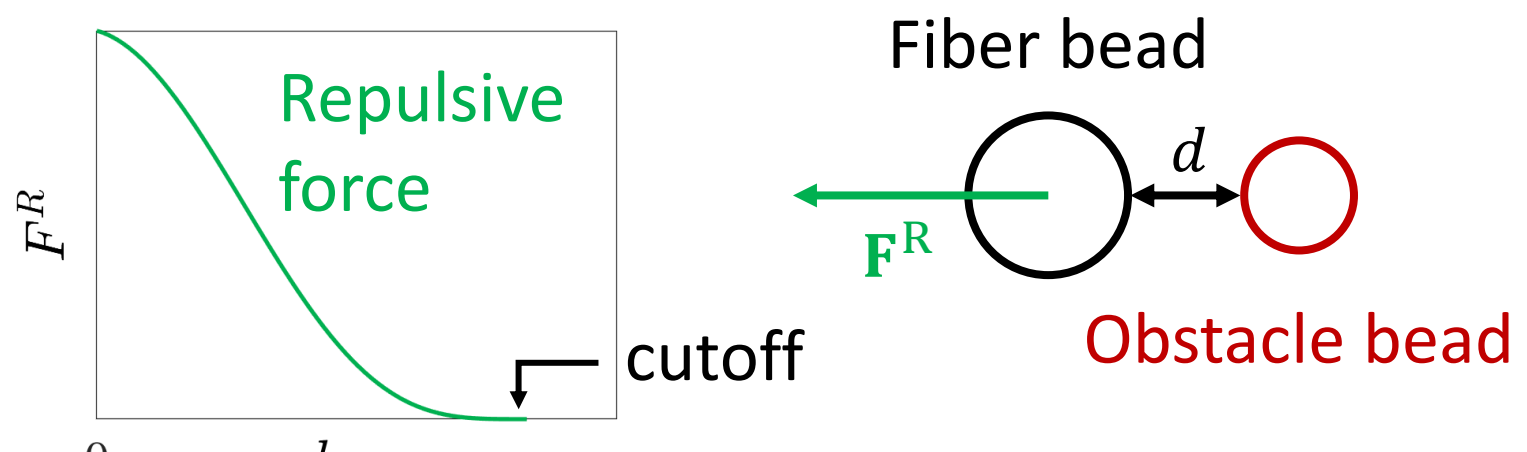
1. Forces applied on the fiber beads

$$\mathbf{F} = \mathbf{F}^S + \mathbf{F}^B + \mathbf{F}^R \quad \mathbf{F}^S + \mathbf{F}^B = -\nabla H$$

Bending Stretching Repulsion

$$H = \sum_{i=2}^n \frac{S}{4a} (|\mathbf{t}_i| - 2a)^2 + \sum_{i=2}^{n-1} \frac{B}{2a} (1 - \hat{\mathbf{t}}_{i+1} \cdot \hat{\mathbf{t}}_i) \quad [1]$$

Stretching Bending



2. Mobility relation

$$\mathbf{U}_i = \sum_j \mathbf{M}_{ij} \mathbf{F}_j + \mathbf{u}_i \quad \text{Ambient flow}$$

Mobility matrix encoding all the hydrodynamic interactions between beads

3. Numerical integration

$$\text{Solve for } \frac{d\mathbf{r}_i}{dt} = \mathbf{U}_i \longrightarrow \mathbf{r}_i^{\text{new}} \quad [2]$$

3. RESULTS

The flow field

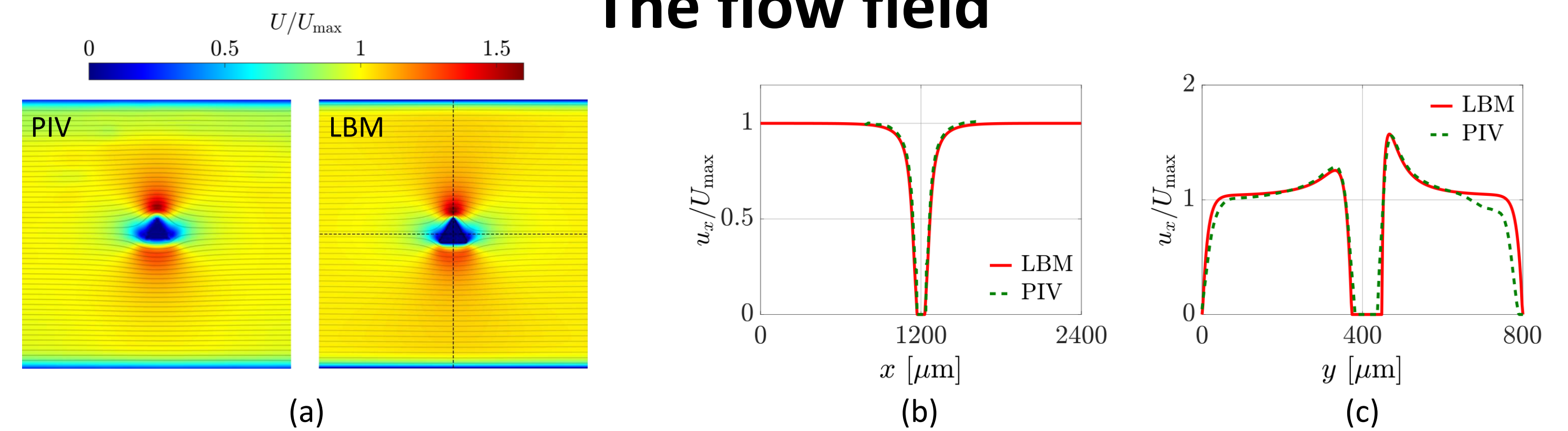


Figure 3. (a) Velocity fields obtained experimentally by PIV and computed numerically by the Lattice-Boltzmann method (LBM). (b) Velocity profiles along the x-axis. (c) Velocity profiles along the y-axis.

Four fiber dynamics

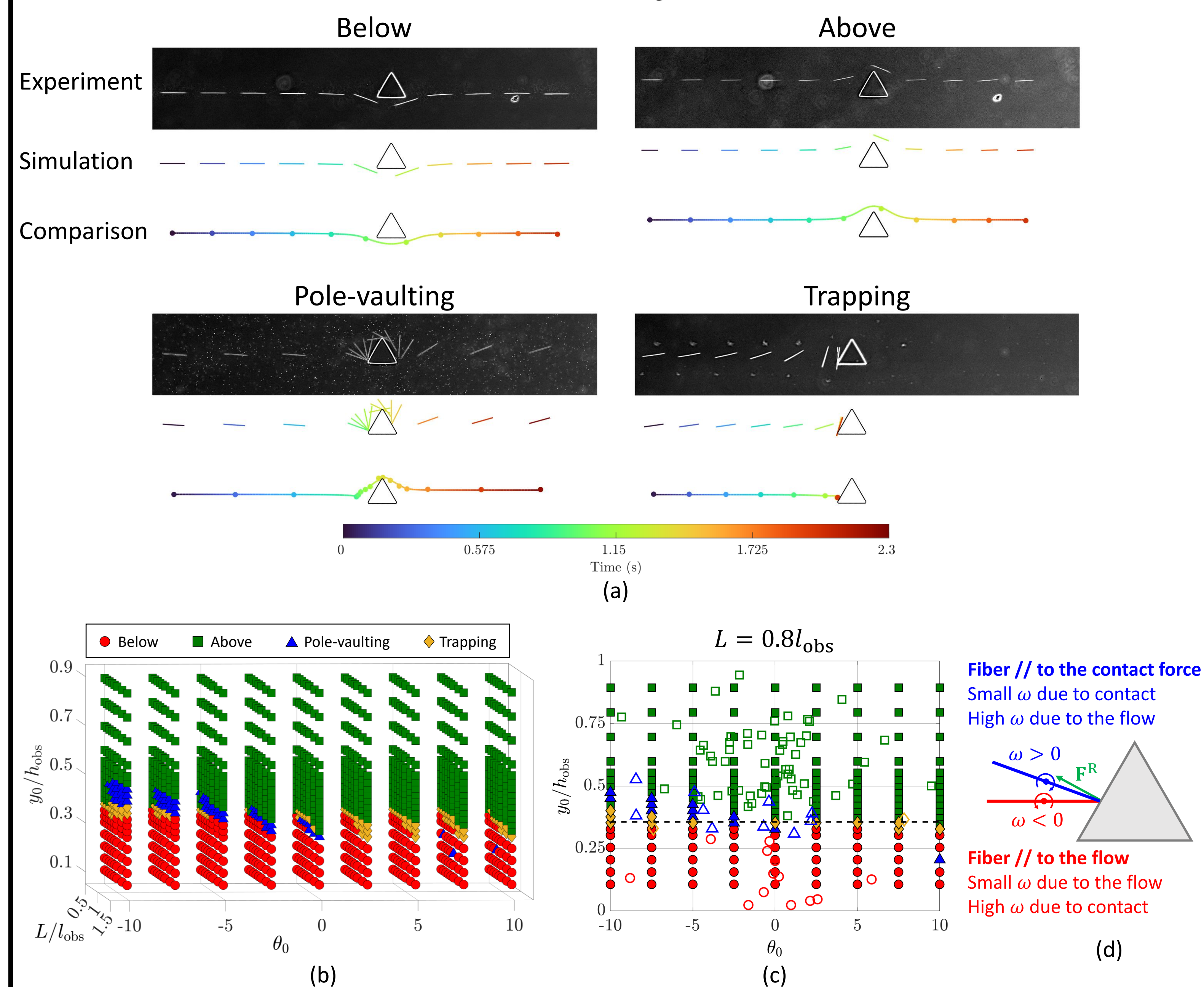


Figure 4. (a) Chronophotographs and trajectories of the four fiber dynamics observed experimentally and reproduced by simulations. (b) The dynamics in the simulations as a function L , θ_0 and y_0 . (c) The dynamics in the experiments (open symbols) and simulations (closed symbols) for $L = 0.8l_{\text{obs}}$. (d) Sketch showing the direction of rotation is the result of a competition between the repulsive force and the flow.

Lateral displacement

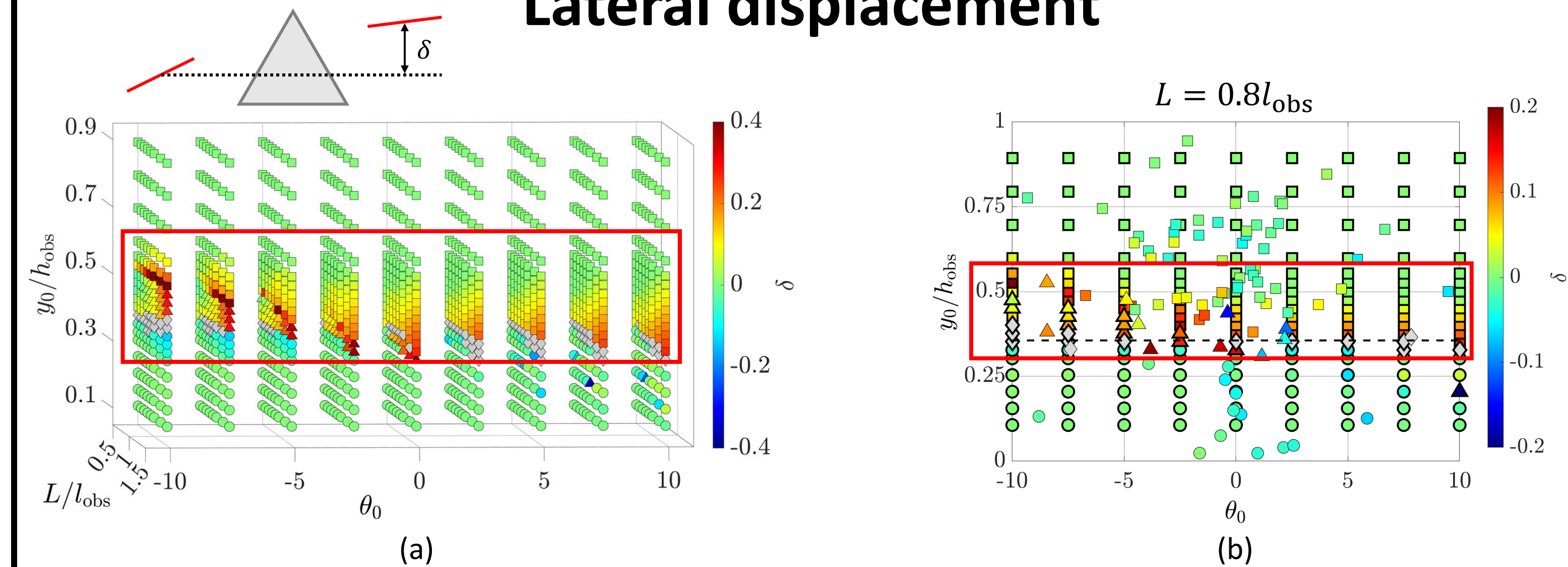


Figure 5. (a) The lateral displacement δ in the simulations as a function of L , θ_0 and y_0 . (b) The lateral displacement in the experiments (thin edges) and simulations (thick edges) for $L = 0.8l_{\text{obs}}$. The red frames show regions where fibers can be sorted by length.

4. CONCLUSIONS AND PERSPECTIVES

- Four different dynamics have been observed experimentally and reproduced by numerical simulations
- The fiber dynamics is the result of a competition between the torque induced by the flow and the torque induced by the contact force
- Longer fibers are more likely to be laterally shifted
- Future works: using multiple pillars to efficiently sort fibers by length and/or deformability