Light-activated Kinesin Tune Defect Density And Nematic Speed

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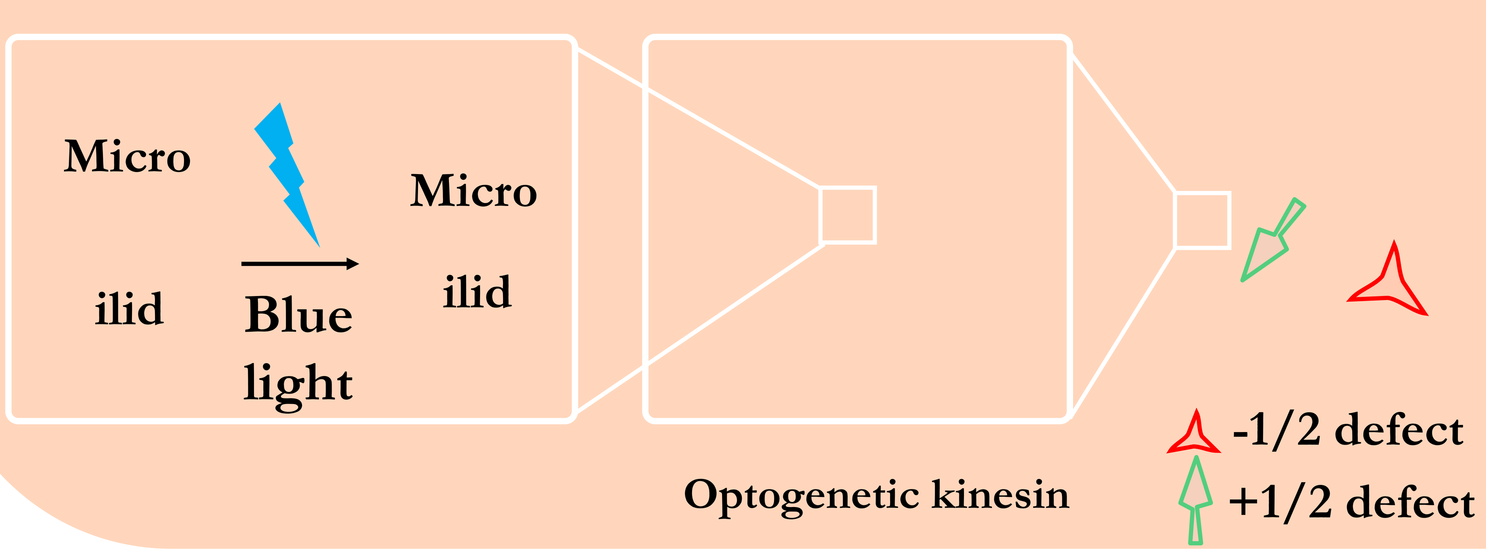
Our question?

Active nematics are intrinsically unstable and unconfined active nematics generate turbulent flows. In order to harness the chemomechanical abilities of these materials to do useful work, these dynamics need to be controlled.
The Brandeis Active Matter IRG2 will address this grand challenge of design and control of active stress, to harness the autonomous dynamics of active materials.
To control the flow and suppress turbulence we developed a 2D active nematic system consisting of microtubule bundles driven by light activated kinesin motor clusters. Here, we investigate how the intensity of uniformly applied light affects active nematic properties. We use particle image velocimetry to calculate the nematic speed and the nematic director field to extract spatial and temporal nematic characteristics, such as the defect density. We find that at low light intensities, the intensity of light is proportional to the nematic speed and the defect density.

Active nematic formed by optogenetic kinesin

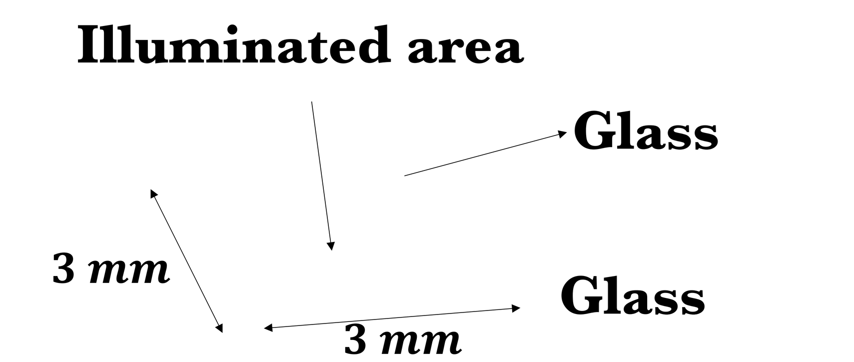
Motor protein walks over the microtubule by hydrolyzing ATP and creates extensile system.
2D active nematics have +1/2 and -1/2 topological defects which exhibit the active nematic dynamics.



Our goal and experimental details

The goal is to control the microtubule-motor protein system dynamics using light to confine the system with light and tune the speed and the active nematic dynamics.

To control the light intensity in space and time, we used a Digital Light Processor (DLP). DLP is a projector composed of digital micro mirrors and a blue light LED ($\lambda = 460$ nm).



Results

The effect of solid walls on the defect density

500

500

The defect density is higher on the walls for both $\pm\frac{1}{2}$ defects
the length scale is 500 micron

Start-up timescale for different intensities

The duration to reach steady state velocity depends on the intensity.

Stopping timescale for different intensities

Stopping timescale [sec]

The time it takes for the system to stop is independent of the intensity.

Experiment

To maintain the active nematic structure for each intensity constant, after every cycle light is on to the max intensity.

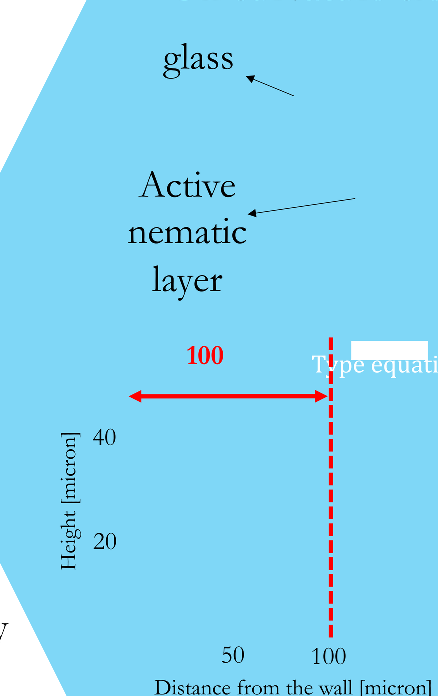
The amount of activation intensity tunes the defect density:
higher light intensity increases the defect density

+1/2 and -1/2 defect density for different intensities

Nematic speed for different intensities

Increasing blue light intensity leads to higher velocity

Oil curvature close to the wall



The sample's oil height is not uniform, is curved at the edges, and decays exponentially.

It decays 5 times faster than the defect density at the boundaries

References and acknowledgement

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