Electronic Supplementary Material (ESI) for Soft Matter
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Topological microfluidics for flexible micro-cargo concepts

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Supplementary Information

Figures S1 - S4

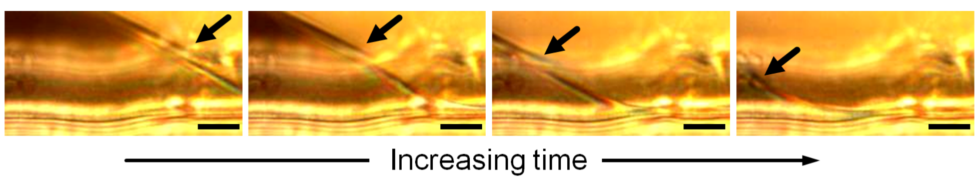

Figure S1: Time sequence of optical micrographs show the collapse of a disclination line (indicated by the black arrow) towards a channel wall. Time separation between images is 2 s. Scale bar: 5 μm.

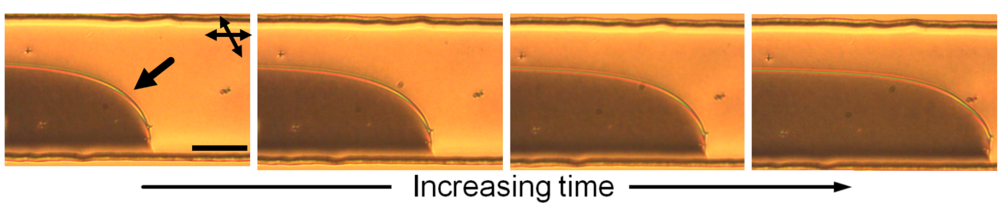

Figure S2: Micrograph time sequence showing a collapsed disclination line separating from the channel wall when flow is started. The black arrow points the disclination. Each image is separated by 2.5 s. Scale bar: 50 μm.

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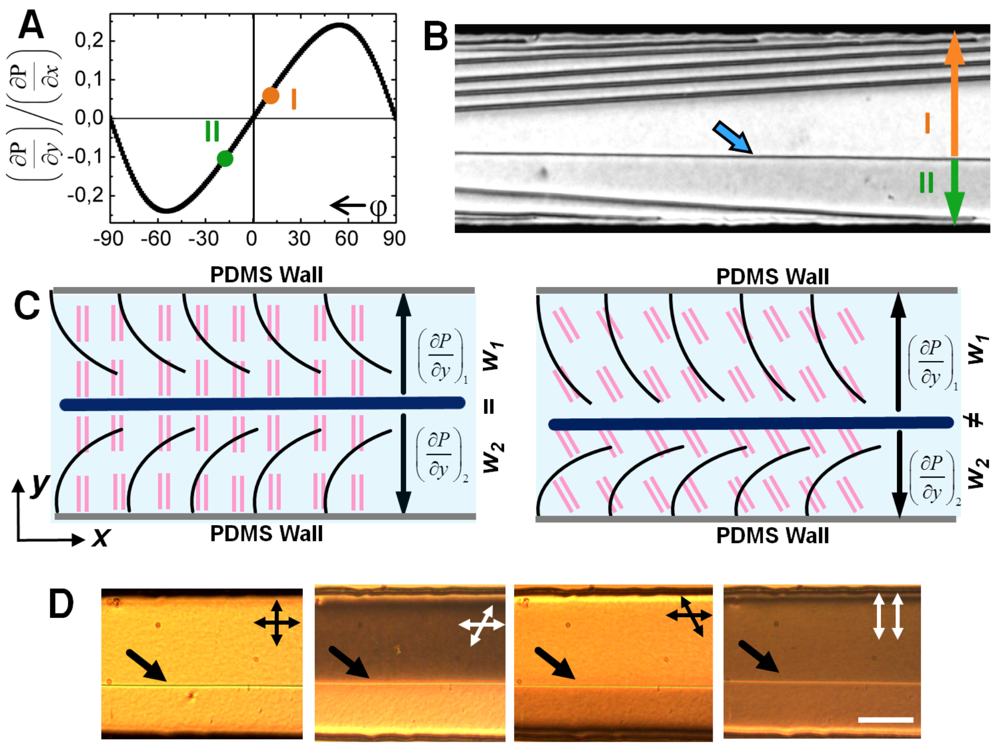

Figure S3: Role of secondary pressure gradient in guiding the soft rail. (A) Variation of the transverse pressure gradient with φ, calculated for 5CB and for each side of the defect line marked by the blue arrow in (B). The gradients corresponding to regions I (width w_1) and II (width w_2) are asymmetrical in this case (green and ochre points). (C) Comparative look at the symmetric (left) and asymmetric director reorientations (right). The parallel pink bars indicate the orientation of the LC anchoring on the glass surface. The curved black lines indicate the orientation of the local director in the presence of the flow field. (D) POM images of the stable disclination line within the nematic bulk, supporting the proposed director schematic in (C). The relative orientation of the polarizers are shown in each micrograph. The director has complementary angles of reorientation about the defect line. Scale bar: 50 μm.

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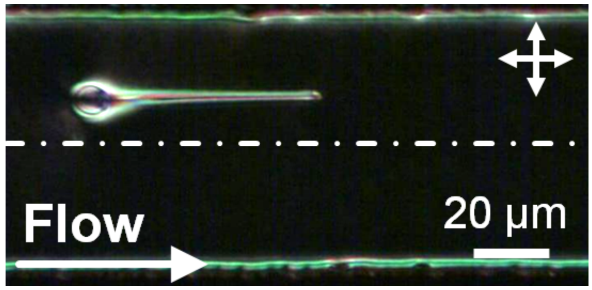

Figure S4: Optical micrograph of a microchannel filled with 5CB flowing from left to right. The 5CB molecules anchor perpendicularly on all walls resulting in the absence of a disclination line. A micro-pillar introduced in the flow path around which a defect line is created that is stretched by the flow. In contrast to Figure 9E, the defect is stretched specifically along the flow direction, demonstrating the absence of a secondary transverse flow.

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Legends for Movies M1 - M5

Movie M1: Laying the disclination track. This movie shows the evolution of a disclination line when a microchannel with suitable boundary conditions is filled with 5CB in the nematic phase. At a flow-separation point, the disclination navigates to the direction where anchoring conditions favor sustenance of the defect line. The movie was recorded under polarizing optical microscopy. The absolute speed of the meniscus is $\approx 50\ \mu$m/s.

Movie M2: Trap-and-transport on soft rail. In this movie we show the process of trapping a colloidal particle on the disclination line. Inclusions close to the defect experience an elasticity-mediated attractive potential. Once trapped, the particle is transported by the surrounding flow field. Far away from the defect line, motion of the colloids within the nematic bulk is determined by the surrounding streamlines.

Movie M3: Principle of the measurement of particle-disclination interaction. The movie shows the principle measuring the particle-disclination interaction. Defect lines along the flow direction offer no resistance to the transport of colloids. On defect lines that make a finite angle with the flow direction, colloids experience competing effects of, on the one hand, a viscous force due to flow and, on the other hand, elastic forces due to the disclination. In the limiting situation, these two effects balance each other. The strength of the particle-disclination interaction was evaluated by determining the viscous force experimentally.

Movie M4: Navigating the disclination line for guided transport at the Y-junction. The movie shows transport of colloidal particles and their aggregates on a declination line navigated to the upper arm of a microchannel. The defect line stably occupies that arm of the Y-junction along which φ, the angle between the director and the flow direction, has a higher value. The colloids docked on the soft rail are guided along this arm.

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Movie M5: In situ switching of the path from one arm of the Y-junction to the other. In situ selection of the target is possible if anchoring conditions in both arms of the Y-junctions are conducive to defect evolution. In this movie, the defect line is initially directed to the upper arm. The existence of another disclination, pinned at the junction and extended in the lower arm, suggests however favorable anchoring in both the arms. The flow in the channel was first gradually reversed and then allowed to continue along the initial direction. It is worthwhile to mention here, that the disclination line can be maintained intact during the gradual reversal of the flow direction. Due care must be observed to avoid any strong fluctuations in the flow field. At the instance of changing the flow direction (reversed relative to the original direction), the outlet pressure at the upper arm was marginally increased to guide the flow − and hence the disclination − to the lower arm. Once the disclination approaches the lower arm, it fuses with the hitherto pinned defect line and stabilizes there.