Study of fluid dynamics at the boundary wall of a microchannel by Bloch surface waves

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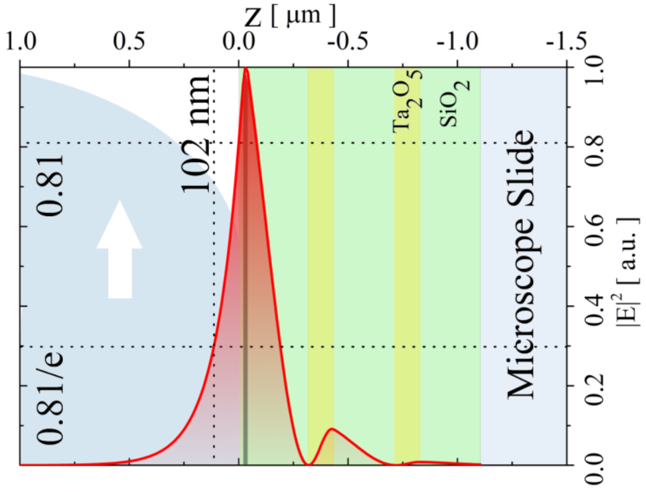
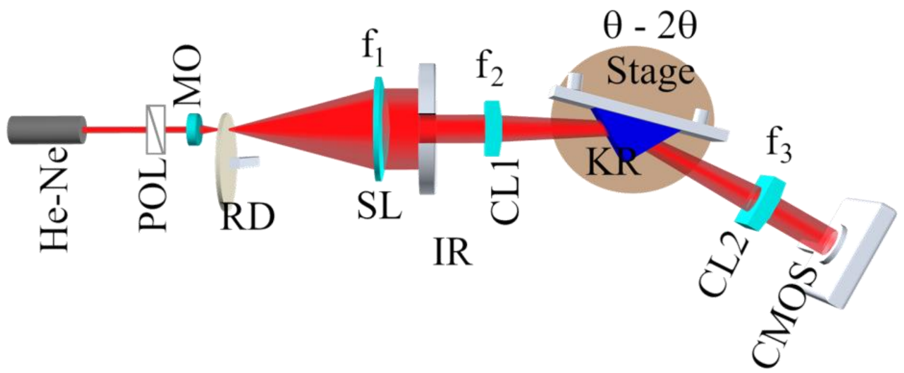
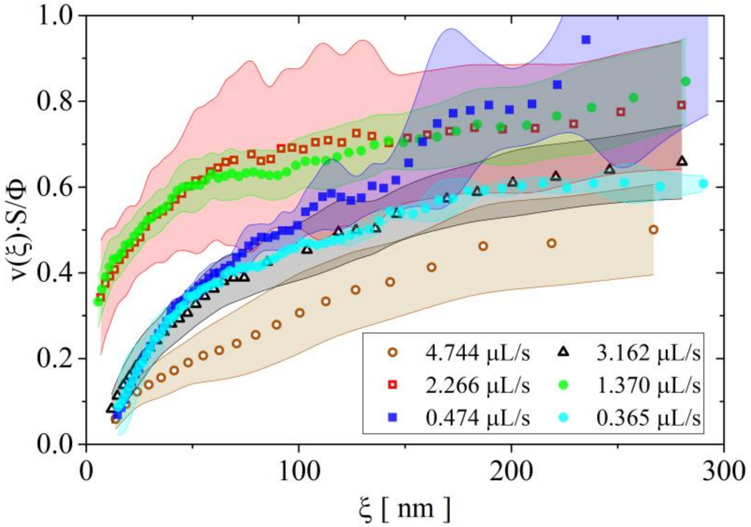
ABSTRACT

Understanding how a fluid flows at the boundaries when it is confined at the micro/nano scale is crucial for a broad range of engineering and biology applications. We propose an experimental technique based on Bloch surface waves sustained by a one-dimensional photonic crystal to evaluate the speed of the contact line in the low Reynold's number regime and with a nanometric resolution.







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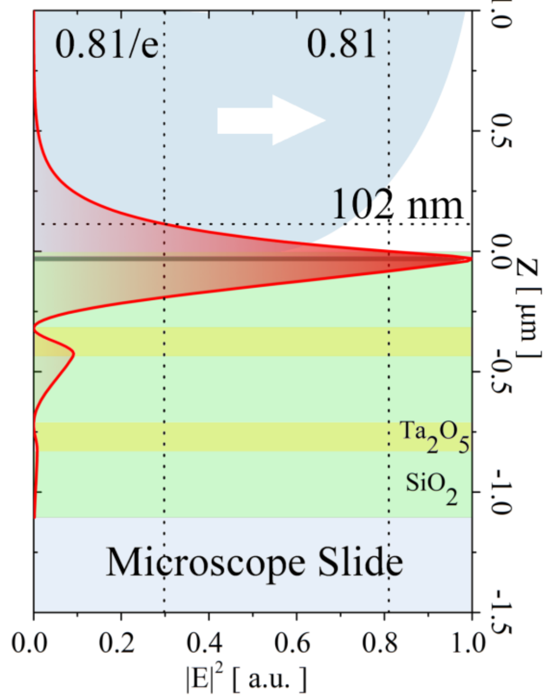
METHOD

Microfluidics. The research area of microfluidics emerged due to the appearance of microtechnology in the early '90s.
The field rapidly developed in several research fields:

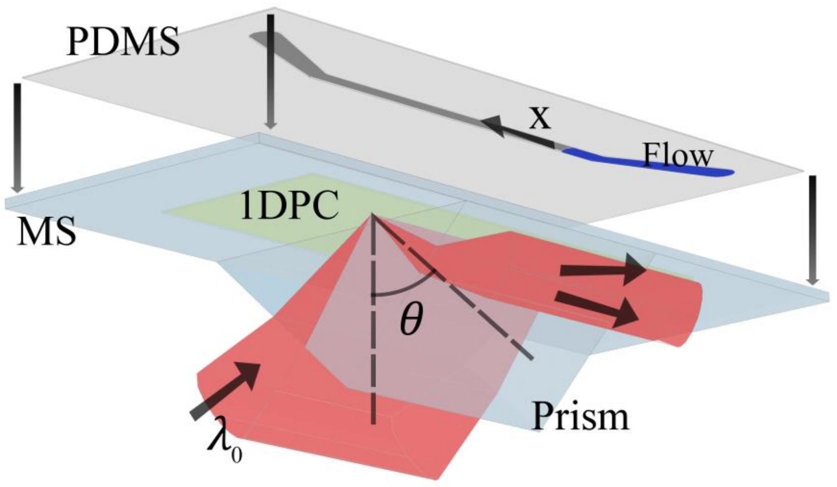
- Chemistry;
- Medicine;
- Biology.

Substantial advantages in terms of integration and fabrication costs.

Bloch surface waves (BSW) are e.m. waves guided at the boundary between a truncated 1DPC and an external homogeneous dielectric medium.



BSWs are localized at the boundary due to Bragg and total internal reflection (TIR) at the 1DPC and homogeneous medium sides, respectively.



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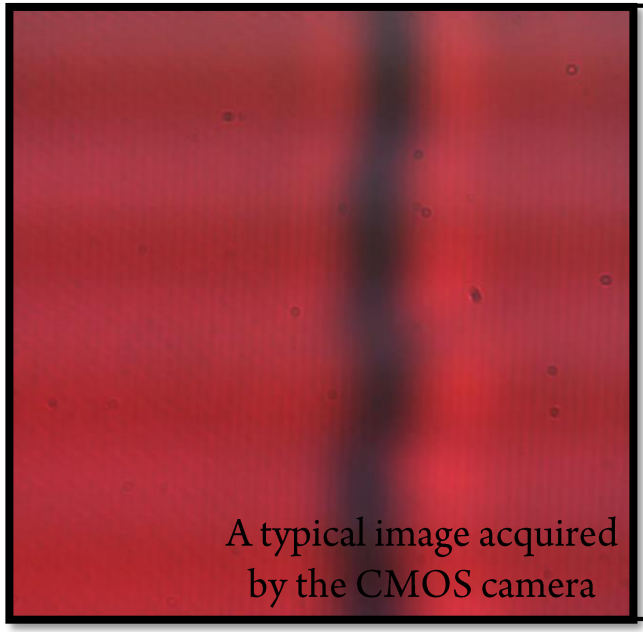
Results

We used deionized water or a 5% glucose solution in deionized water.

$\Delta n_{max} = 7.35\times10^{-3}$

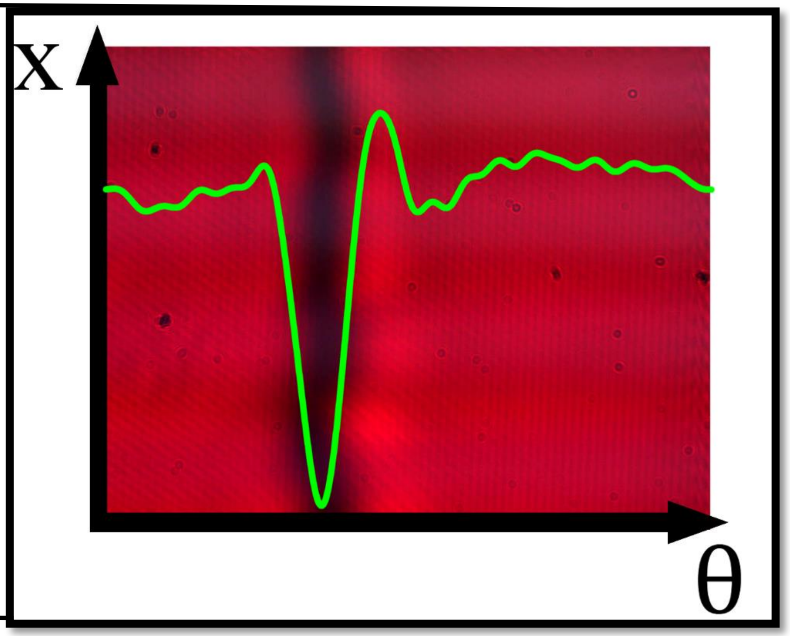
The excitation of a BSW shows up as a resonant dip in the angular reflectance spectrum.

l_H=3.69 mm (1024 pix)



A typical image acquired by the CMOS camera

$\Delta\theta$ = 1 deg (1280 pix)



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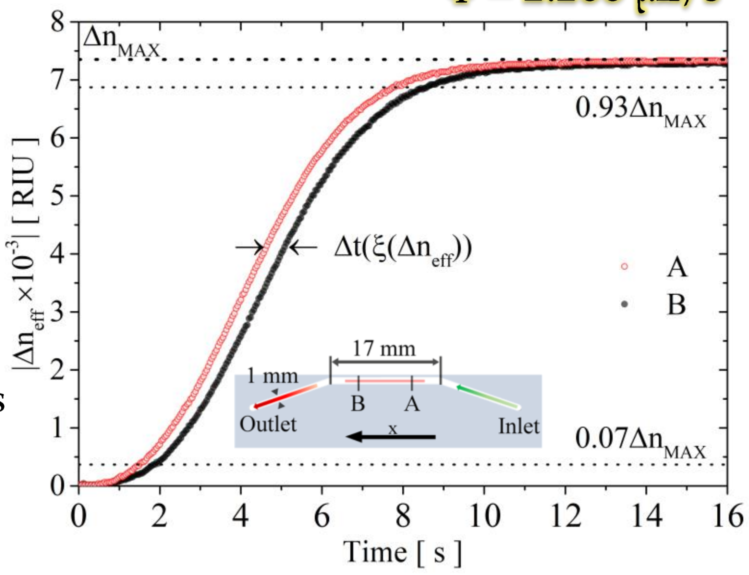
DISCUSSION

- Plot of the $\Delta n_{eff}(x,t)$ in the positions A and B along the flow direction x.
- The points are separated by $\Delta x = 3.24$ mm.
- A temporal delay between the two signals can be resolved.

A was closer to the channel inlet

The refractive index increase was observed earlier than in **B**

$\Phi = 2.266\ \mu L/s$

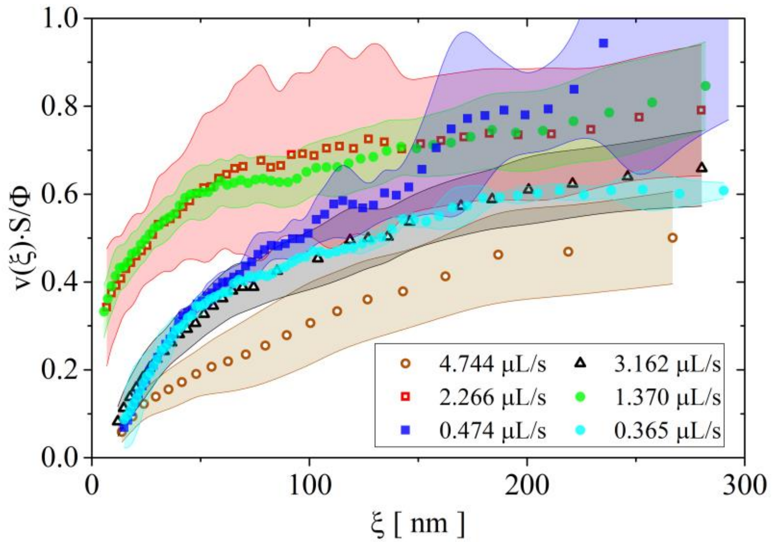


The velocity of the contact line as a function of ξ is then given by:

$$v(\xi) = \frac{\Delta x}{\Delta t(\xi)}$$

We plot the velocity normalized to the average velocity across the channel:

$$v_N = v(\xi) \cdot \frac{\Sigma}{\Phi}$$



$\xi_{min} = 7$ nm

$\xi_{max} = 280$ nm

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Conclusions

1. The results obtained are **qualitatively consistent with the theoretical model developed by Ledesma-Aguilar et al.**. The slip velocity in the vicinity of a solid boundary arises naturally in diffuse interface models, which consist of the usual Navier–Stokes equations coupled to a convection–diffusion equation.

2. The measurement of the contact line velocity at different distances from the boundary wall is carried out with a **nanometric resolution**.

3. Within the limit imposed by diffusion of chemical species in the liquids, we think that the technique could be **useful for velocimetry measurements at distance from surface not accessible by other techniques**, such as the μ-PIV for example.