

The project set out to develop a polymer-based optofluidic lab-on-a-chip platform to study the physical dynamics of biological macromolecules. Increasing the ability to handle and study nano-scale molecules on a small chip facilitates the development of devices that could find use in genetics research, point-of-care diagnostics, criminal forensics and categorisation of endangered species. To this end, the innovation of this work focused on the development of two novel optical techniques that can be engineered to be highly sensitive and suitable for integration with fluidic nanochannels. The first of these, photonic crystals, can be used to monitor subtle perturbations of refractive index that are induced by the presence and disposition of the biomolecules. The second approach, plasmonic V-grooves, can be used to form the nanochannel itself while simultaneously performing other unique optical functions on extended molecular conformations. Both of these approaches were polymer-based in this work, offering an affordable and feasible path for up-scalability of device development for widespread implementation.

Several challenges related to the behaviour of the polymer-based photonic crystals were critical to address in order to be used as intended. To start, two distinct enhancements to the sensitivity were reported in this research. The first of these involved an optimised high refractive index layer of TiO_2 (Figure 1(a, b)), which may be directly integrated with fluidic channels. The second of these relates to a swelling polymer film, which promotes their use as gas and low concentration particle sensors (Figure 1(c)).

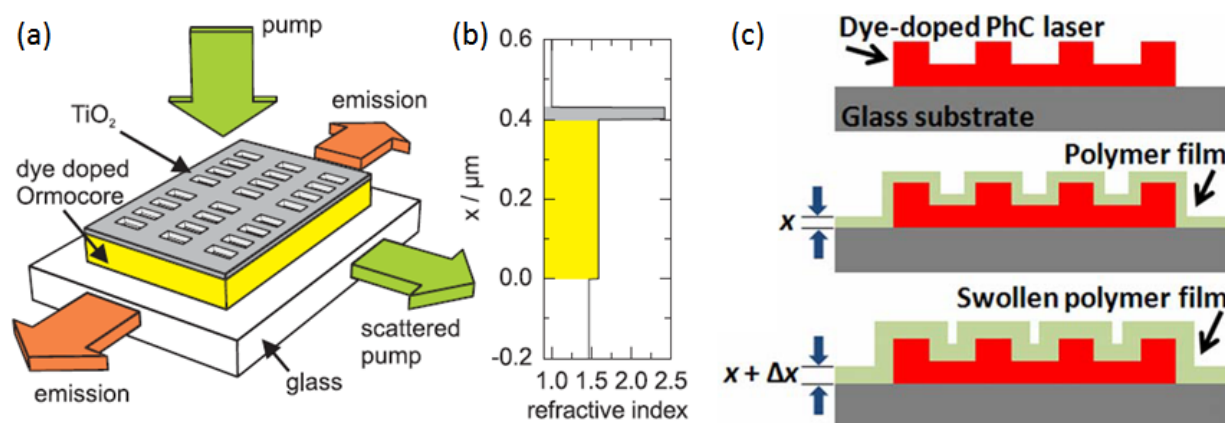


Figure 1. (a) Schematic of a hybrid polymer-TiO₂ dye laser. (b) Corresponding refractive index profile of such a laser with a sensitivity-enhancing 30 nm TiO₂ layer. (c) A polymer film is shown to swell (Δx) during exposure to specific gases, increasing its sensitivity.

The use of photonic crystals to redirect light for targeted sensing in lab-on-a-chip devices was studied, understood and engineered in this research via two methods. The first of these explored the effect of disorder of the photonic crystal (Figure 2(a)) to reduce color-based dispersion while still obtaining the desired diffraction. The second of these explored the integration of liquid crystals (Figure 2(b)) to accurately direct light to certain target “pixels”.

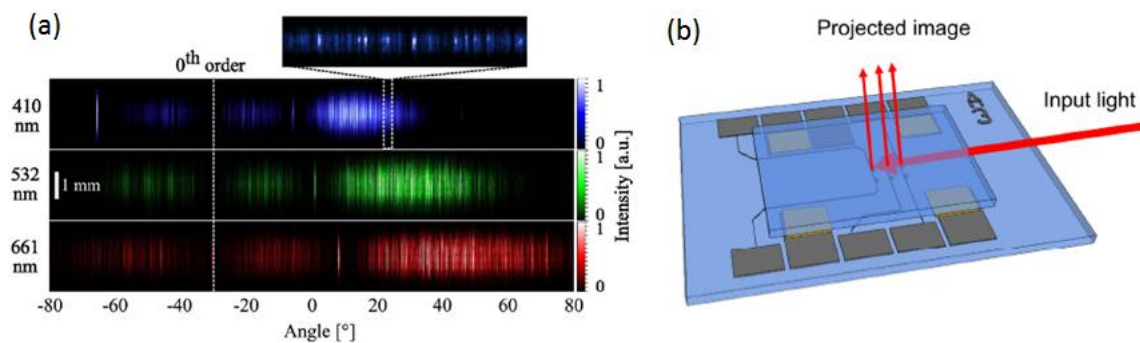


Figure 2. (a) Transmitted diffraction patterns from a disordered grating. (b) Light enters from the side and is controllably out-coupled perpendicular to the device plane at specific locations. The liquid crystal layer enables electrical modulation of individual pixels.

Plasmonic V-grooves represent a unique platform to study biomolecules, owing to their unique intensity distributions. Their affordable fabrication via nanoimprint lithography and component sophistication was summarily addressed during the Action (Figure 3).

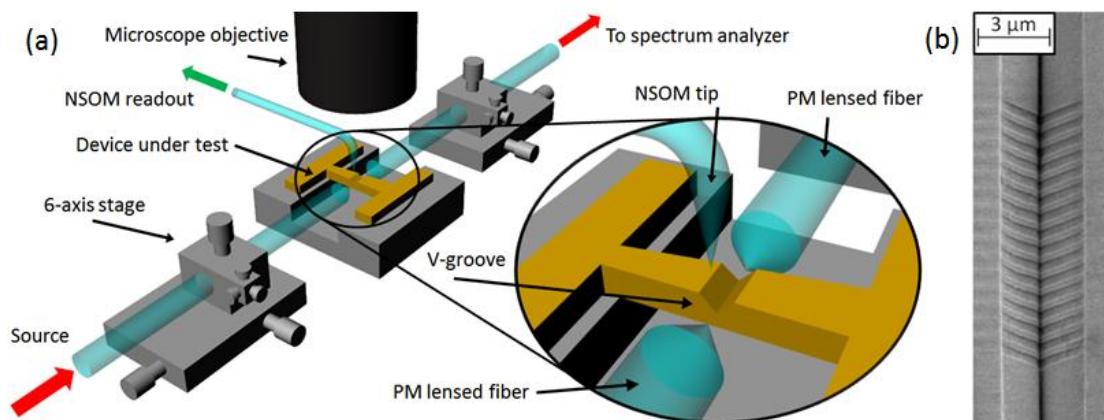


Figure 3. (a) Characterising plasmonic V-grooves: a scanning near-field tip may simultaneously probe the localized electric field intensity while light is coupled to the V-groove. (b) Tilted scanning electron microscope image of a V-groove containing a Bragg grating filter.

The research goals of the project continue to be pursued in newly established projects that are based on the progress achieved in this Action. Accordingly, the quality of the research undertaken is validated and highlights the importance of the research to societal needs. The scientific and practical competences of the participant have been notably developed during this period in addition to a significant transfer of knowledge to two PhD students and a Masters student.

All of the published results represent significant contributions to the scientific community, as the improvements can be generalized and applied to similar but alternative approaches. The achievements represent advancements not only to biomolecular research but also extend to other fields within the greater lab-on-a-chip paradigm, high speed photonics, interior lighting and heads-up-displays.