

# Optical reading of single cells mechanical properties with slow Bloch mode cavity

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## Short abstract:

The last decade, many studies have been focusing on the mechanical phenotype of biological cells as a new physical biomarker. Indeed, the mechanical properties of cells are influenced by the onset and progression of diseases. For instance, Malaria and Sickle Cell Anemia are associated with a reduction of Red Blood Cells (RBCs) deformability. Hence, a precise determination of the cellular mechanical response can be essential to bring new insight for better diagnostics. For this purpose, we aim at exploring a new biophotonic approach applied to the characterization of cell deformability. The originality of our approach relies on the all-optical reading of cell deformability using the resonant mode of photonic crystal (PhC) micro-cavities. The presence of an object on top of a PhC micro-cavity induces a local change of refractive index associated with a spectral shift of the resonance spectrum. We propose to investigate the extension of this concept to the measurement of cell deformability in order to get a mechanical signature of the cell. In this work, we demonstrate the proof of principle of our approach by the detection of RBCs deformability using a PhC micro-cavity. Moreover, we have shown for the first time that the variation in reflectivity spectrum of a photonic cavity could allow discriminating between healthy RBCs and artificially rigidified ones.

## Summary

It is now well established that changes in cell mechanics are hallmarks of many human diseases. Here we propose an original approach developed at INL to study the mechanical properties of single cells. One major innovation of this approach is the all-optical reading of cell deformability using the resonant mode of photonic crystal micro-cavities. We have demonstrated for the first time that our device can efficiently discriminate between healthy and mechanically impaired RBCs.

## References

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### **Long abstract:**

The past decades have seen a considerable growth in research on the exploitation of cellular mechanical properties as an indicator of their physio-pathological state. For instance, Malaria and Sickle Cell Anemia are associated with a reduction of Red Blood Cells (RBCs) deformability. In this context, the scientific objective of our approach relies on the all-optical reading of cell deformability using the resonant mode of photonic crystal (PhC) micro-cavities. In this work, we demonstrate experimentally the proof of principle of our approach. The refractive index contrast due to the presence of the cell over the PhC micro-cavity creates an instantaneous perturbation of the optical mode. One manifestation of this perturbation is a red-shift of the resonance wavelength. The magnitude of this shift is a function of the cavity field overlap with the cell. Therefore, the larger the cell deformation, the larger is the shift.

The experimental setup uses relies on two optical beams. A trapping laser beam that is used to position first the RBC on the cavity and, once positioned, to deform it in a controlled manner thanks to radiation forces. The second beam is a broadband source used to monitor the reflectivity spectra of the PhC micro-cavity.

The experiments were conducted on healthy RBCs (hRBCs) and artificially rigidified RBCs (rRBCs) to evidence the effect of the cell deformability on PhC cavity resonance. The experimental results clearly show the impact of the optical forces and hence the deformation on the cavity resonance. A 65 pm shift is detected for hRBCs whereas a significant lower shift (30pm) is observed for the mechanically stiffer rRBCs. The results are even more striking when discussed as the reflectivity variation, near the cavity resonance. For the hRBCs, a reflectivity variation of 350% which is attributed to the large deformation of the cell above the cavity, whereas a variation of 110% in reflectivity is obtained for rRBCs. We will also explain the observed behavior thanks to optical simulation (FDTD and FEM).

These important experimental results show that our approach can be used to qualitatively discriminate between deformable and stiffer micro-objects such as biological cells. Such approach can provide a promising novel approach for the identification of pathological cells within a sample.