

Silica nanoparticles to image cells in water by picosecond ultrasonics

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Picosecond acoustics enable the mechanical characterization of transparent media by means of Time Domain Brillouin Scattering (TDBS) detection in the GHz frequency range and at the micrometer scale¹. This technique is based on the interferences of a probe light with a propagating acoustic wave. The transparent sample, biological cells in the framework of our researches, is placed on a 300 nm thick titanium layer sputtered on a sapphire plate. The sapphire acts as a heat sink to protect the cells from laser induced damages. Two trains of laser pulses of duration 400 fs are delivered by a dual-oscillator. One of the laser trains is used as a pump of wavelength 1030 nm and the other is used as a probe of wavelength 515 nm. Both lasers have the same repetition rate but they are slightly shifted to perform an asynchronous optical sampling (ASOPS).

We have demonstrated recently that silica nanoparticles, whose size matches the wavelength of phonons at the Brillouin frequency, can be used to discriminate the Brillouin oscillations in a soft transparent medium immersed in water². Indeed, the multiple scattering of waves cancels the coherent acoustic propagation in water and consequently attenuates the Brillouin oscillations in the fluid whereas the Brillouin signature of the transparent medium remains unaffected.

In this work, we apply this technique to improve the opto-acoustic imaging of biological cells immersed in water. Indeed, for ten years³, picosecond ultrasonics has been used to image the mechanics of biological cells. However, until now for most experimental achievements, the cells are dried and fixed on the opto-acoustic transducers (Fig 1 (a)). Few experiments have been done with immersed cells⁴⁻⁵ (Fig 2 (a)) whereas it is an essential step toward the achievement of the characterization of living cells.

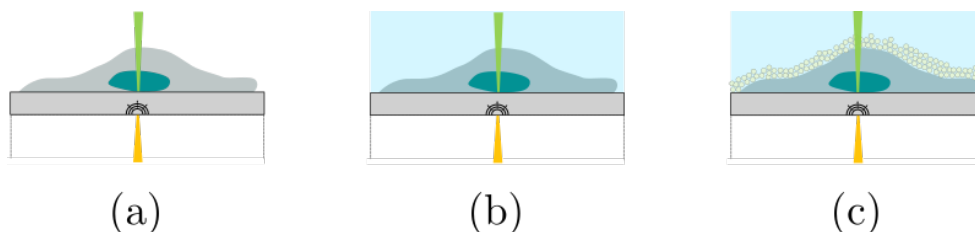


Fig 1: Experimental configurations: deshydrated cell on the titanium/sapphire optoacoustic transducer (a); immersed cell in water (b); cell covered by a sediment of silica nanoparticles (c).

A sediment of nanoparticles is deposited on a mesenchymal stem cell and the system is immersed in water (Fig 1 (c)). Elastic waves are generated by the pump beam at the sapphire-titanium interface, propagates in the titanium layer and are transmitted through the cell at the titanium-cell interface.

The spectrum of the reflectivity signal recorded in different part of the cells is analyzed for the three configurations presented on figure 1 : deshydrated cell (a), immersed cell in water (b), and cell covered by the sediment of nanoparticules and immersed in water (c). Fourier transform and time-frequency analysis of the reflectivity signal are performed and compared. Finally, successive acquisitions by step of 1 μm are made to achieve a mapping of the cell covered with nanoparticules. The Brillouin frequency of each signal is extracted and represented as a function of the position. The resulting frequency image is compared to the optical image.

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