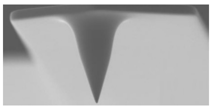
FAIT d'ACTU . June 2023



Towards a new generation of acoustic imaging

Although laser ultrasound imaging is now recognized as a powerful tool for investigating elastic properties in a wide range of fields, from applications to fundamental research, a number of obstacles remain. The generation of acoustic fronts by femtosecond lasers, with wavelengths of a few tens of nanometers, ensures excellent depth resolution, but has so far failed to achieve such resolution in the layer plane.

To solve this problem, researchers from INSP's Acoustics for Nanosciences team have proposed coupling optical pump-probe approaches with near field microscopy concepts, paving the way for 3D acoustic imaging on the scale of a few nanometers.

Acoustic imaging first and foremost requires an acoustic source. In order to achieve 3D imaging, this source must satisfy certain criteria:

- The generation of very high-frequency acoustic waves. For several decades now, this has been solved through the absorption of femtosecond laser pulses, which generate ultra-short stress fields of just a few picoseconds through the thermo-elastic effect. The corollary is the creation of coherent acoustic fronts with nanometers wavelengths.
- In addition, the lateral size of the source must be nanometric. So far, it's the weakest point. Laser excitation beams are generally focused in the far field by microscope lens. As a result, it's difficult to go much below the optical wavelengths of laser sources, i.e. 800-400nm.
- The source must be mobile on the surface of the system to be characterized. This last element disqualifies acoustic sources obtained by vibrational relaxation of individual objects, which were envisaged a few years ago but whose positional control on the surface is proving more than problematic.

The proposed experimental geometry, fig. 1a, has the advantage of simultaneously resolving the points raised above. Focusing the pump beam on the cantilever enables the generation of a high-frequency acoustic packet (50 GHz) which, by propagating along the axis of the tip, produces an acoustic source confined to its apex. This source can then be easily moved over the surface of the system to study.

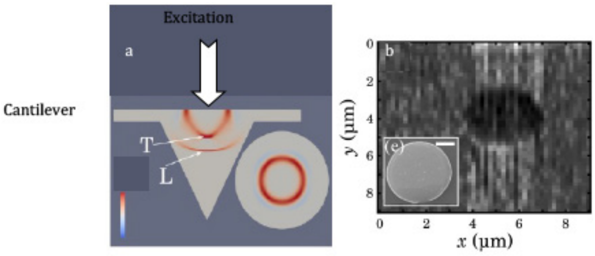


Figure
a) Schematic diagram of excitation. A finite element simulation is used to describe for the guidance of a longitudinal L and transverse T wave.
b) Impedance mapping on a gold silicon substrate. The lateral resolution estimated here is of the order of 250nm, i.e. a factor of 10 lower than the resolution achievable with conventional acoustic imaging.

In this geometry, we have first validated that the acoustic echo reflected by the tip's apex enables acoustic impedance mapping at scales well below those permitted by far-field focused probe pump beams, fig 1b. We have also demonstrated the transduction of a longitudinal wave from the tip to the sample, opening the door to 3D imaging.

These initial results are based on longitudinal wave synthesis, while the creation of transverse waves carrying additional information has yet to be fully understood. The resolution limit needs to be quantified for both surface and volume imaging. The filtering of high frequencies by the nature of the tip-sample contact is also an aspect that needs to be taken into account. The wide variety of tip shapes readily available on the market are also tracks for optimization that will need to be exploited in the future.

Reference

"Towards acoustic microscopy at the nanoscale by coupling atomic force microscopy with picosecond ultrasonics"
R. Delalande, D. Garcia-Sanchez, and L. Belliard
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