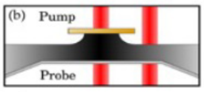

Designing acoustic sources adjusted in frequency and size

Nano-objects have many properties that have led to applications in recent years, particularly in the field of optics. From the point of view of elasticity, these systems, whose size can go down to a few nanometers, were initially considered to test the limit of validity in size of the hypothesis of the mechanics of continuous media. Neverthless, very quickly the question of the coupling of these resonators with the environment emerged. Strategies were found to reduce this coupling to obtain resonators with a very high quality factor, for example by working on self-suspended 1D systems. An inverse way, was to take advantage of this coupling in order to create new adjustable acoustic sources at high frequency (>100GHz). In this context, the members of the «Acoustics for Nanosciences» team of INSP have developed a hybrid approach integrating these two aspects in order to create acoustic sources adjustable in frequency as well as in size.

The generation and detection of vibrations confined to nano-objects are obtained in a so-called «pump-probe» geometry allowing to trace the resonance modes of these entities. The pump beam allows the generation by photo-thermal effect and the probe ensures the detection thanks to the photo-elastic effect. The shape, the material, the texture, the size, are all intrinsic parameters allowing to control the frequency and the nature of these modes. To fix orders of magnitude, a gold particle of a hundred nanometers will resonate at frequencies of the order of several tens of GHz. On the other hand, the coupling of the object with the substrate leads to an energy leakage materialized by a fast damping of the vibration modes. By imposing an emission frequency through the size of the excited object, we implicitly create a link between the frequency and the size of the acoustic source, which usually leads to a source emitting in a wide angular spectrum. In this context, the INSP team, using nano-structuring approaches in clean room, has outlined a new approach allowing to obtain acoustic sources operating at very high frequencies and where one of the dimensions can be adjusted without changing the frequency.

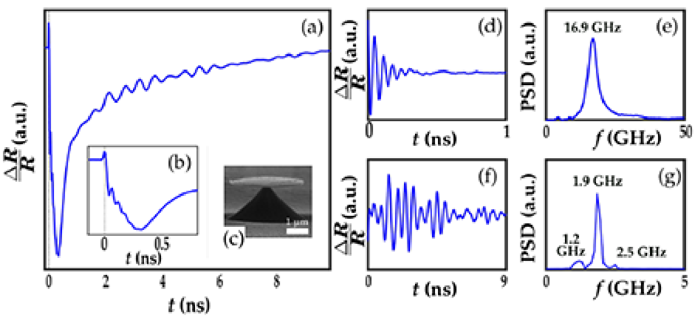

Figure 1
a) and b) Time evolution of the reflectivity change of a gold disk of 3.4µm diameter and 100nm thickness. c) Geometry of the partially self-suspended nanostructure. d) and f) Extraction of the oscillating behaviors of the two contributions. e) Spectrum of thickness modes. g) Spectrum of radial modes.

The excitation of a gold microdisk (Figure 1c) by a femtosecond laser pulse results in a vibrational landscape composed of two classes of modes, some correlated to the diameter and others, at much higher frequencies, to its thickness (Figure 1). The former are strongly dependent on the boundary conditions and thus on the adhesion zone with the substrate, resulting in a reduction of the resonance frequencies observed during the undercutting. This tendency can be mimicked by a reduction of the elasticity due to the relaxation of the boundary conditions becoming free. As for the thickness modes, not very sensitive to the size of the contact zone, they will be the vector of the monochromatic emission in the substrate. With the help of a mapping of the displacement fields in time and space, the emission of longitudinal acoustic waves resulting from the excitation of the latter could be demonstrated (Figure 2). The size of the emission area is independently controlled by the etching time.

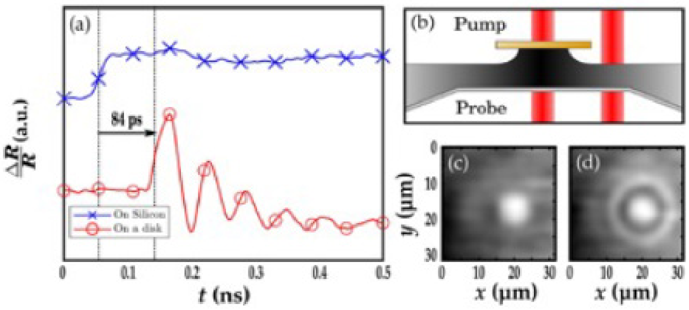

Figure 2
a) Variation of the reflectivity measured on a disk. b) Geometry of the measurement. c) and d) Mapping of the emitted waves with a time interval of 60ps.

If this work unequivocally demonstrates the possibility of creating acoustic sources that can be controlled both in frequency, in the range of several hundred GHz, and in size, in a largely sub-micron range, the possibility of controlling the position of such sources still remains to be addressed. Indeed, in the perspective of the realization of acoustic maps resolved in depth and in the plane, at the scale of ten nanometers, this point constitutes a lock that should still be unlocked. Some tracks are currently under study by integrating near field microscopy probes.

Reference

"Substrate influence on the vibrational response of gold nanoresonators: Towards tunable acoustic nanosources"
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https://hal.archives-ouvertes.fr/hal-03551835/

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