

Optomechanical detection of vibration modes of single bacterium

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Vibration modes of biological particles such as proteins, viruses and bacteria involve coherent structural vibrations at frequencies in the THz and GHz domains. These vibration modes carry information on its structure and mechanical properties that play a pivotal role in many relevant biological processes. Despite the rapid advances of optical spectroscopy techniques, detection of vibration modes of single bioparticles has remained elusive. Here we harness a particular regime in the physics of mechanical resonator sensing that serves for detecting them. By depositing single bacterium on the surface of ultra-high frequency optomechanical disk resonators, we demonstrate that the vibration modes of the disk and bacterium hybridize when their associated frequencies are similar (Figure). A general theoretical framework is developed to describe the different regimes that can be found when an analyte adsorbs on a mechanical resonant sensor. The model recovers the classical inertial mass sensing regime as a limit case of a more general problem. Theory, numerical calculations and experiments show excellent agreement, allowing to retrieve the eigenfrequencies and mechanical loss of the bacterium vibration modes. Our method is applied for analysis of the effect of hydration on the vibrational properties of a single bacterium. This work opens the door for a new class of vibrational spectrometry based on the use of high frequency mechanical resonators with the unique capability to obtain information on single biological entities [1].

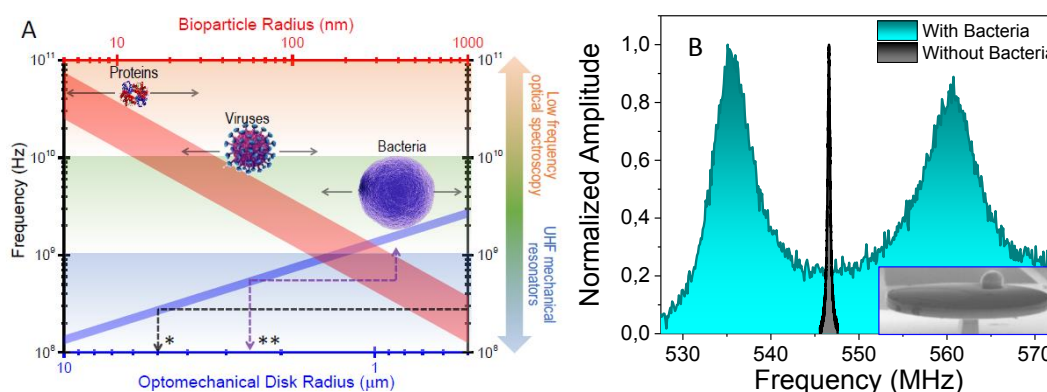


Figure. A. Frequency of the radial breathing mode of a 320 nm thick disk (blue region) and of the fundamental mode of a quasi-spherical bioparticle adsorbed on a rigid support (red region), as a function of their radii. **B.** Effect of bacterium adsorption on the radial breathing mode of an optomechanical disk (Radius=2.5 μm , Thickness=320 nm). The inset shows a scanning electron microscopy image of the optomechanical disk with an attached *Staphylococcus epidermidis* cell.

This work was supported by the European Union's Horizon 2020 under grants agreement no. 731868 – VIRUSCAN, 681275 – LIQUIDMASS- ERC- CoG-2015 and 770933-NOMLI-ERC-CoG 2017. E. Gil-Santos acknowledge financial support by the Spanish Science and Innovation Ministry through the projects PID2019-109765RA-I00 and RYC2019-026626-I.

References:

- [1] E. Gil-Santos, et. al. "Optomechanical detection of vibration modes of single bacterium". *Nature Nanotechnology*, 15, 469-474 (2020).