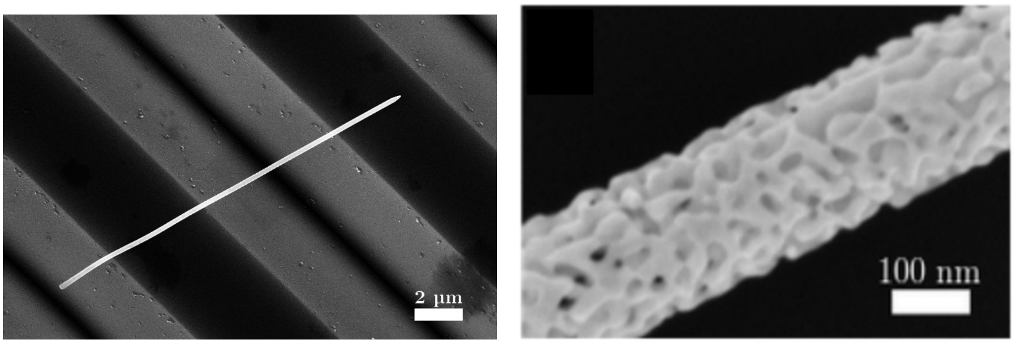
Determining Elastic Properties of a Single Metallic Nanoparticle using Time-Resolved Ultrafast Spectroscopy

Ronan Delalande[1,2], Laurent Belliard[1]

[1] *Sorbonne Université, CNRS UMR 7588, Institut des NanoSciences de Paris, INSP, F-75005 Paris, France.*
[2] *Laboratoire d'Acoustique de l'Université du Mans (LAUM), UMR 6613, Institut d'Acoustique – Graduate School (IA-GS), CNRS, Le Mans Université, France*

Metallic nanoparticles are the key elements for numerous applications. This is partially due to confinement which deeply modifies the properties of a nano-object compared to its bulk counterpart. In particular, thermal as well as elasticity properties and phenomena at the nanoscale can be deduced from their vibrational properties. That's the reason why they're extensively investigated. Picosecond ultrasonics have proven to be a very efficient way to investigate both ensemble and single metallic nanoparticle. It has been used to study the vibrational response of nanoparticles displaying a large diversity of shape, material and size.



Scanning Electron Microscopy images of a single Au nanowire standing over a pre-structured substrates and of a single porous gold nanowire

Among this diversity, one may distinguish nanowires. Taking advantage of their high aspect ratio and pre-structured substrate, such nanoparticle can be investigated experimentally as a free standing nano-object allowing to study its eigen modes freely from any environment coupling [1]. Thereby, the resonant frequency of its radial modes, especially its breathing modes, can be measured using time-resolved ultrafast spectroscopy. Those modes can also be expressed analytically via the PochHammer-Chree equation which displaying those frequencies dependence on both size and elastic properties (Young's modulus and Poisson's ratio) of the media. Knowing both the size of the nanowire and several breathing mode frequencies, an inverse method allow to obtain the properties for a single nanowire.

This technique has been employed to obtain the elastic properties of nanowires made of a single metal (e.g. Au or Ag). It has also been used for nanowires displaying complex heterostructures, AuAg alloy in that case [2]. Finally, it can be used to monitored properties in various environment (e.g. as a function of temperature).

[1] Belliard, L., et al. *Journal of Applied Physics* 114.19 (2013): 193509

[2] Delalande, R., et al. *Applied Physics Letters* 115.8 (2019): 083103