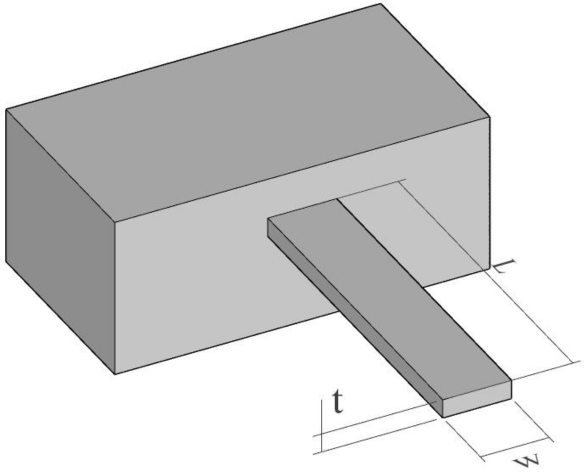
Dispositivos micromecânicos para caracterização de materiais

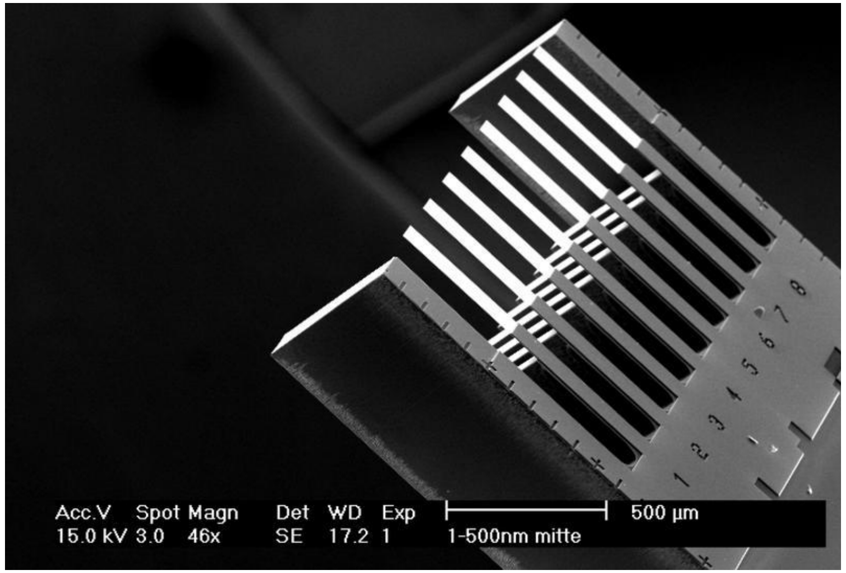
Gustavo Marcati Alexandrino Alves
gmarcati@usp.br

Conteúdo

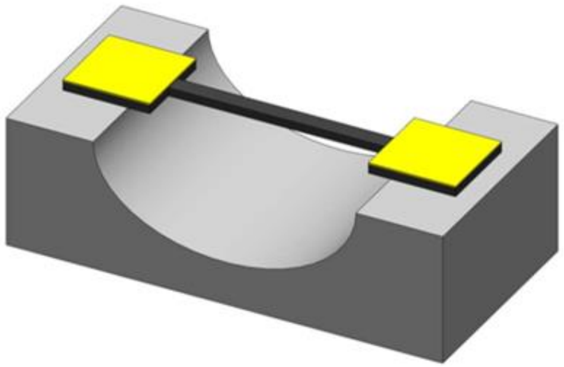
Introdução

O Microcantilever é um dos dispositivos MEMS mais simples





Fonte : https://www.sciencedaily.com/releases/2013/02/130214075439.htm



Fonte : https://www.nature.com/articles/s41378-019-009

Tamanhos usuais:
L= 100 - 500 μm
w= 20 - 100 μm
t=0,5 μm - 10 μm

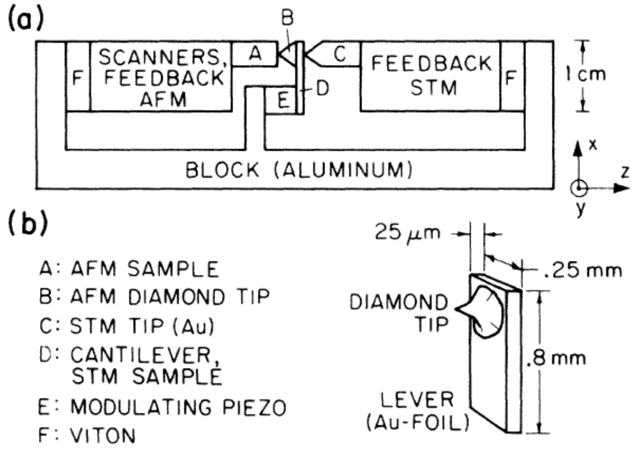
Introdução

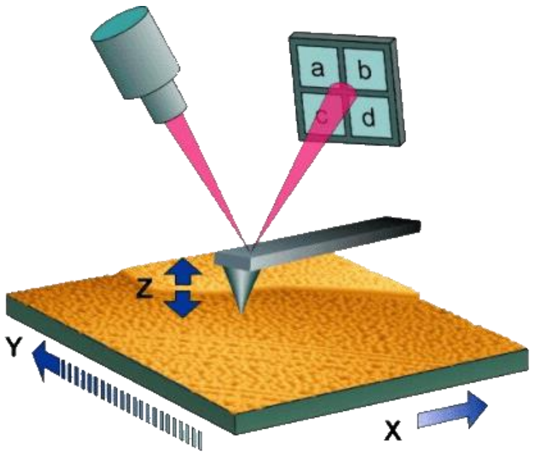
1986 – Invenção do AFM na IBM

VOLUME 56, NUMBER 9 PHYSICAL REVIEW LETTERS 3 MARCH 1986

Atomic Force Microscope

G. Binnig[a] and C. F. Quate[b]
Edward L. Ginzton Laboratory, Stanford University, Stanford, California 94305
and
Ch. Gerber[c]
IBM San Jose Research Laboratory, San Jose, California 95193
(Received 5 December 1985)

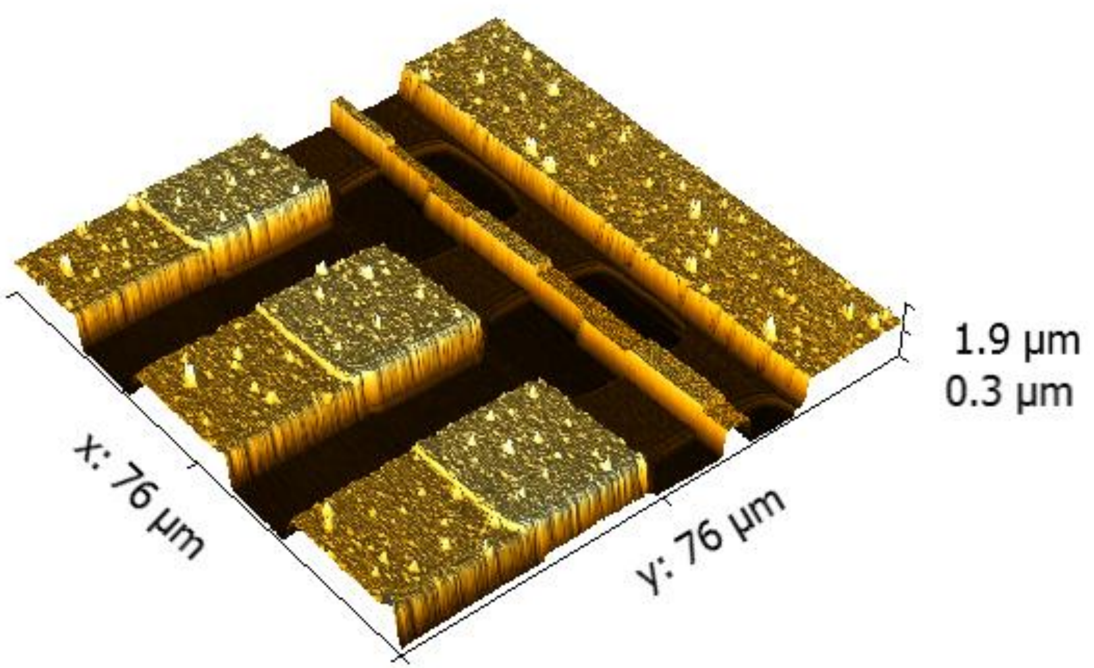




A ampla utilização do AFM popularizou os cantileveres micrométricos.

Introdução

Imagem AFM de uma cascata de transistores MOS (USP -2016)

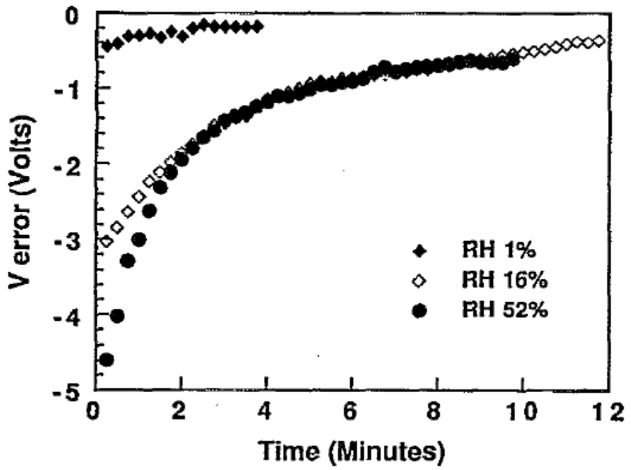


Introdução

- 1994 – Primeira utilização de microcantilever do AFM como sensor

Thermal and ambient-induced deflections of scanning force microscope cantilevers

T. Thundat, R. J. Warmack, G. Y. Chen, and D. P. Allison
Oak Ridge National Laboratory, Oak Ridge, Tennessee 37831-6123



. 1. Error voltage as a function of time for a microfabricated silicon de cantilever with 40 nm gold overlayer for three different relative hu-

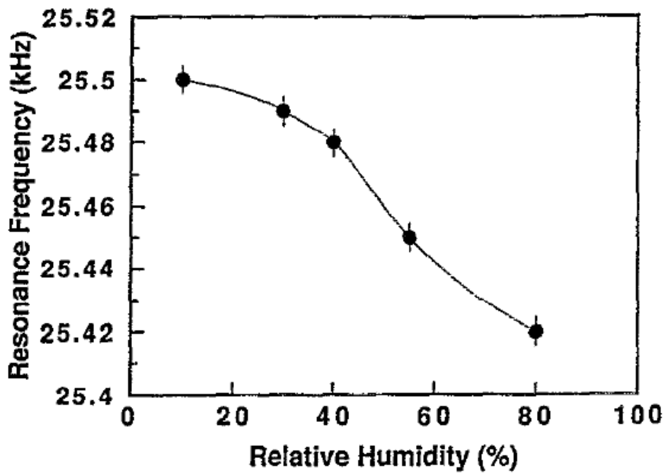


FIG. 3. Typical variation in resonance frequency as a function of relative humidity for an uncoated silicon cantilever (K=0.03 N/m).

- Mudanças de temperatura, umidade etc. causavam problemas nas imagens (*drift*)

Introdução

- 2000 Primeira utilização de microcantilever para reconhecimento molecular de pares de DNA

Translating Biomolecular Recognition into Nanomechanics

J. Fritz,[1,2] M. K. Baller,[1,2] H. P. Lang,[1,2] H. Rothuizen,[1] P. Vettiger,[1] E. Meyer,[2] H.-J. Güntherodt,[2] Ch. Gerber,[1]* J. K. Gimzewski[1]

We report the specific transduction, via surface stress changes, of DNA hy-

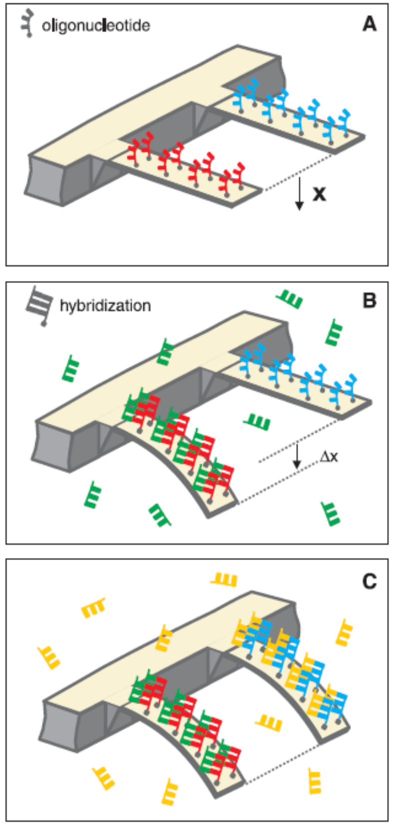
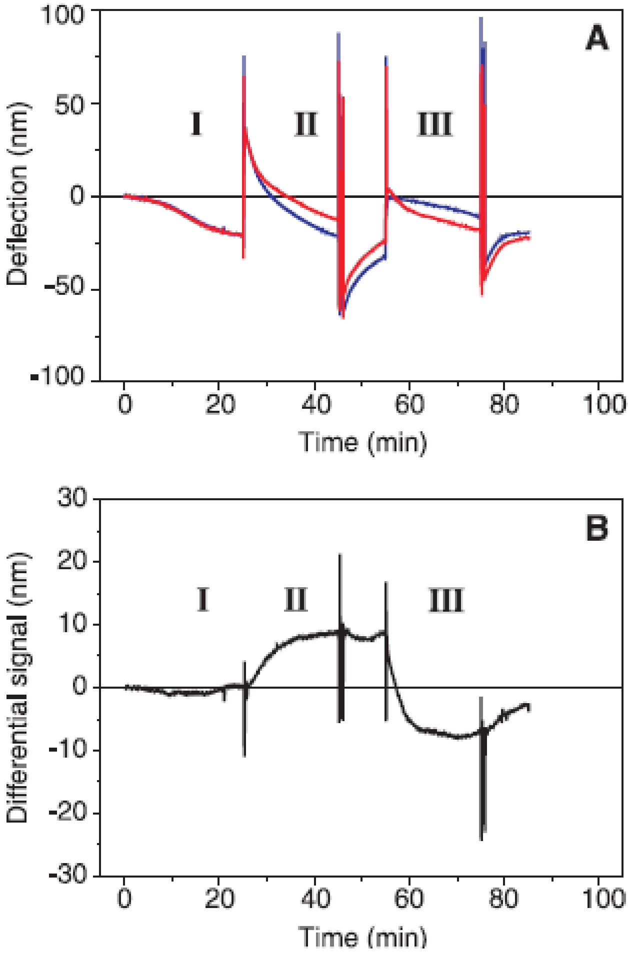
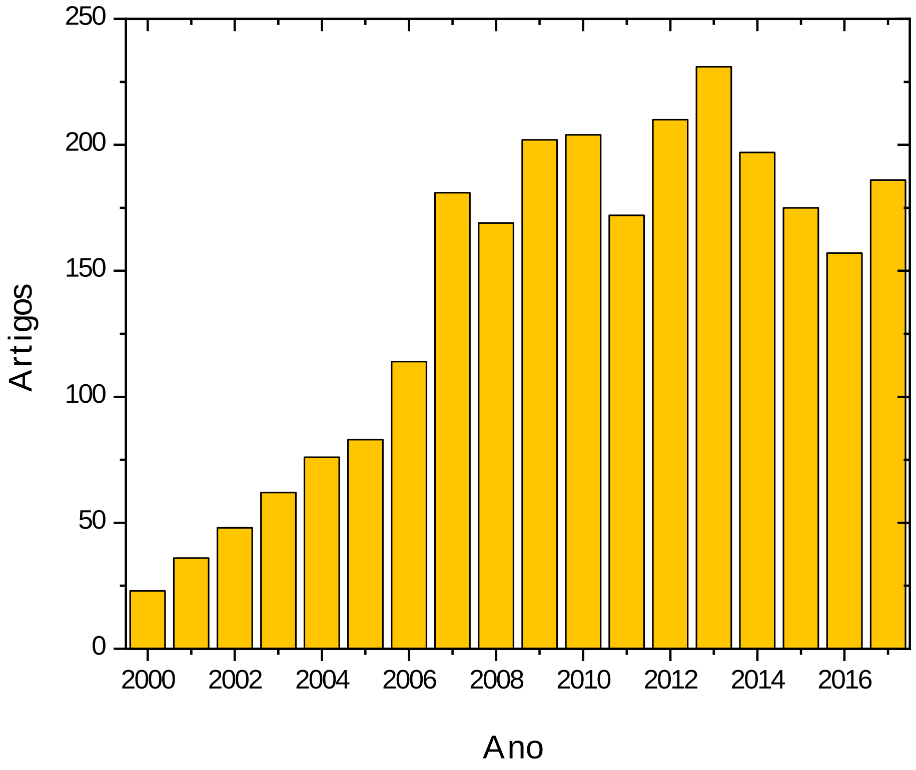


Fig. 2. Scheme illustrating the hybridization



Introdução



Artigos contendo “microcantilever sensor”
Total de 2526 artigos nos últimos 17 anos

1 - Simples fabricação;

2 – Sensível;

3 - Versátil (múltiplas aplicações);

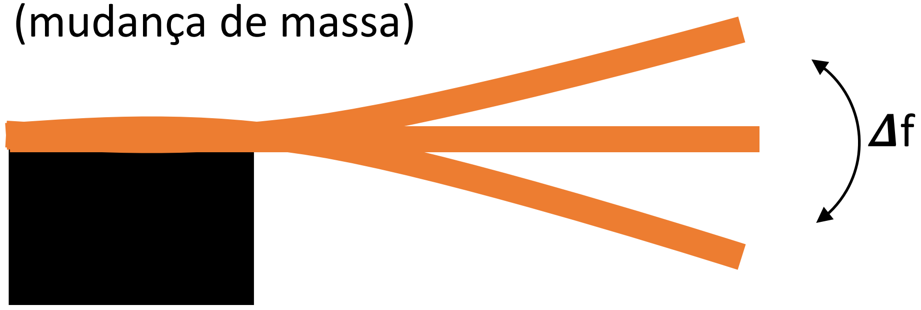
Introdução

Princípio de funcionamento

Deflexão estática
(stress superficial)

- Biosensores (reconhecimento biológico)
- Sensores de temperatura
- Nariz eletrônico
- Caracterização de materiais

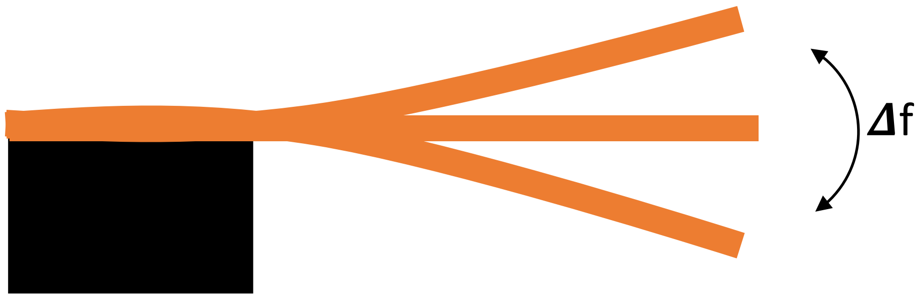
Frequência de ressonância
(mudança de massa)

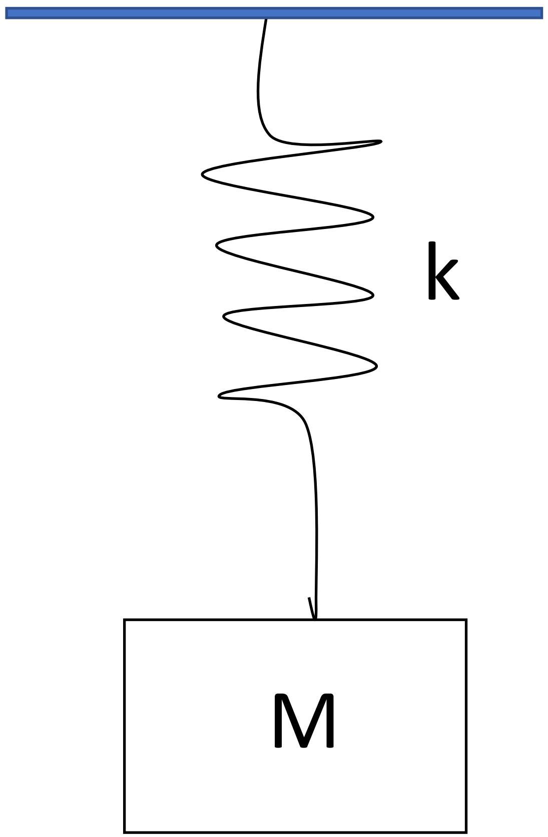


- Espectroscopia de massa
- Sensores de viscosidade
- Microfone
- Caracterização de materiais

Introdução

Modelo





$$f = -k\,x$$

$$f = m\frac{d^2x}{dt^2}$$

$$-k\,x = m\frac{d^2x}{dt^2}$$

$$x(t) = \ sen(wt)$$

$$\dot{x}(t) = -w\,cos(wt)$$

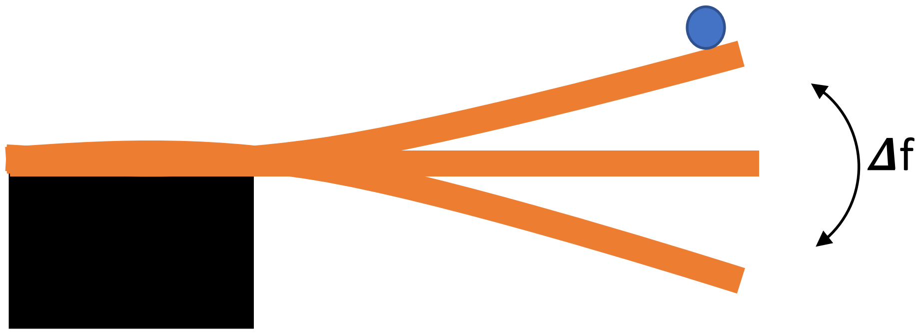
$$\ddot{x}(t) = -w^2\,sen(wt)$$

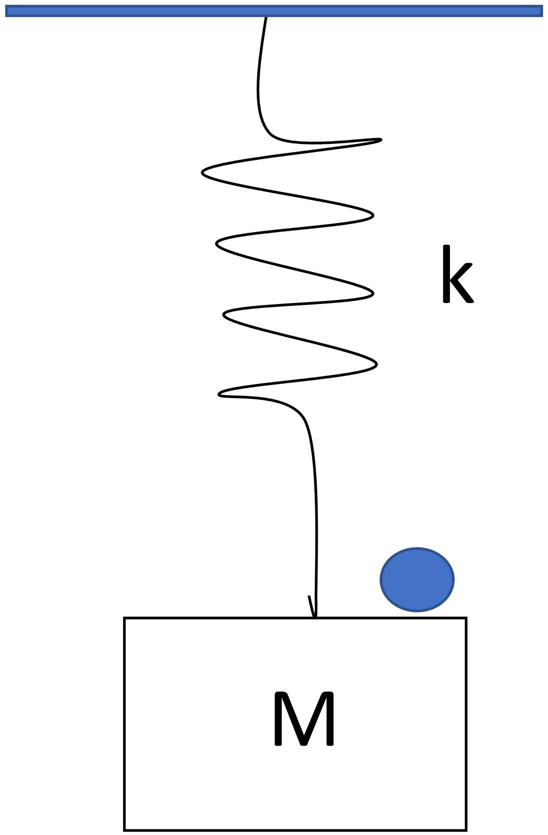
$$-k\,sen(wt) = -mw^2\,sen(wt)$$

$$w = \sqrt{\frac{k}{m}} \qquad w = \sqrt{\frac{k_{eff}}{m_{eff}}}$$

Introdução

Modelo





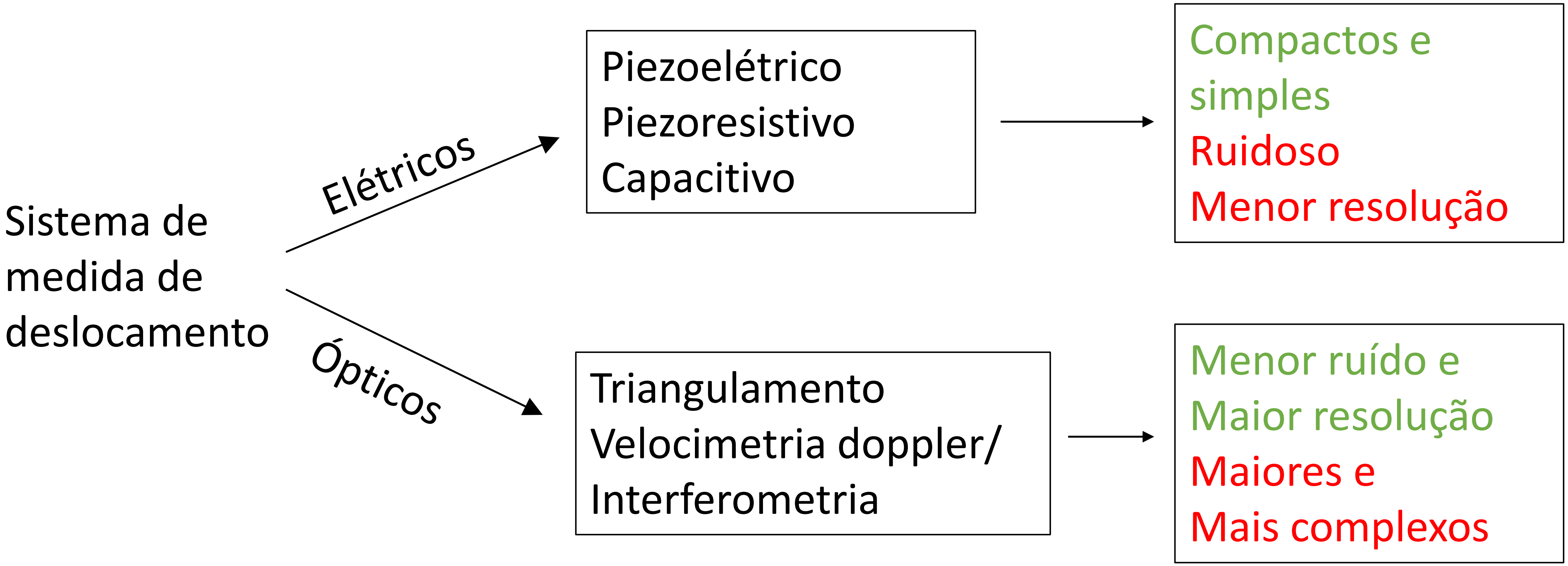
w= $\sqrt{\frac{k_{eff}}{m_{eff}}}$

$$S = \frac{dw}{dm} = \frac{w}{2m}$$

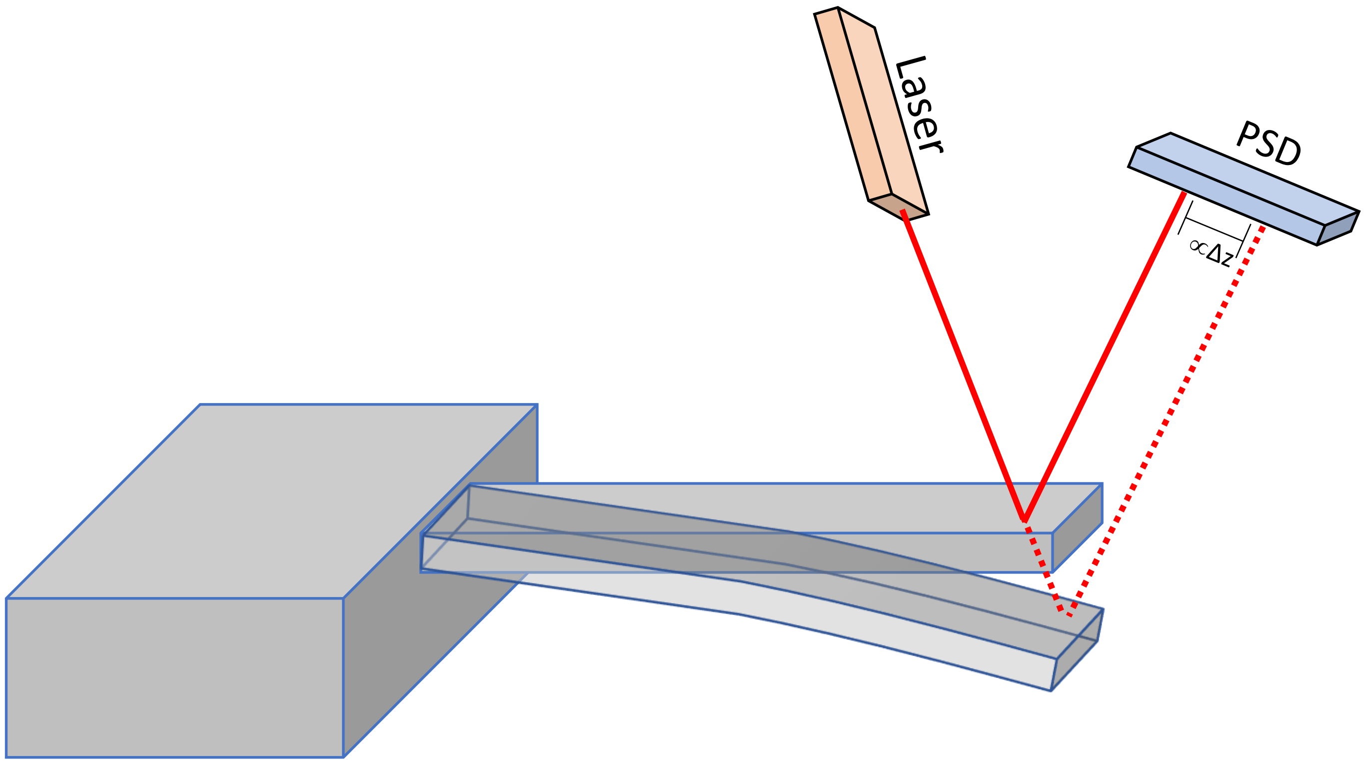
w= $\frac{{\alpha_n}^2}{L^2}\sqrt{\frac{E\ I}{\rho\ A}}$

$$\alpha_1 = 1{,}875, \alpha_2 = 4{,}6941, \alpha_3 = 7{,}854$$

Sistemas de medidas



Sistema de medidas óptico por triangulamento

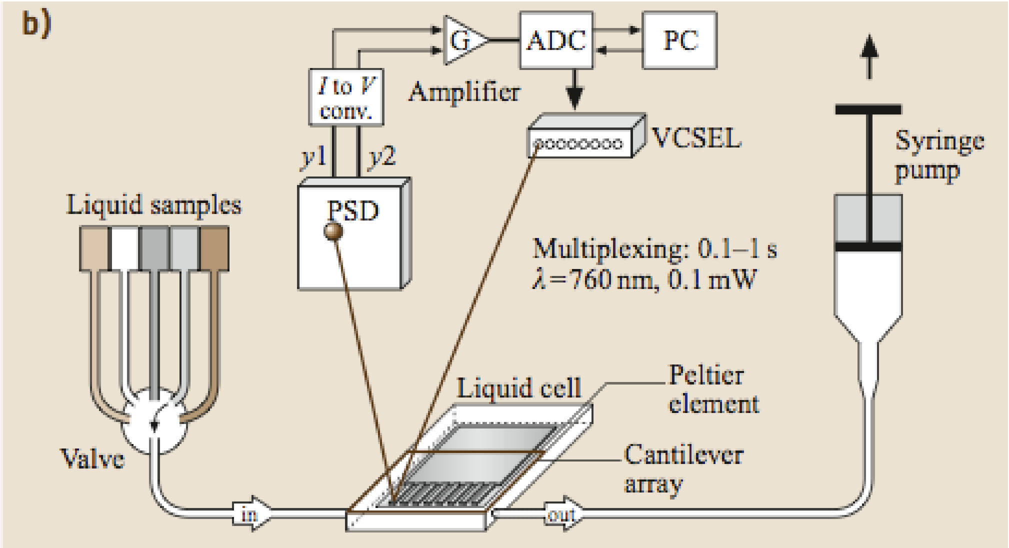


Sistema por triangulamento

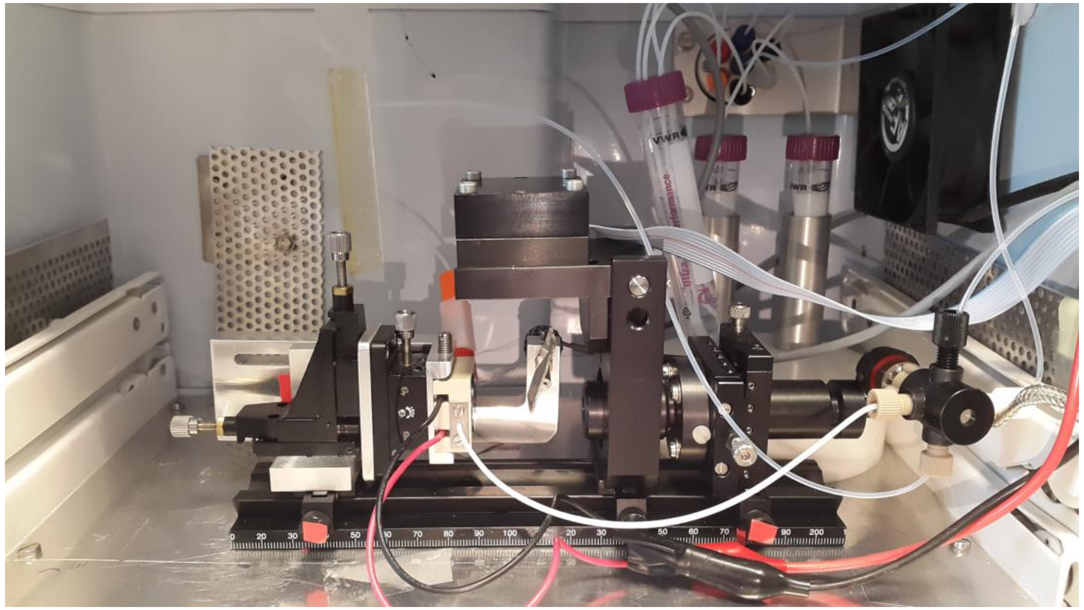
- Utilizado em microscópios AFM
- Simples
- Não possibilita a leitura diferencial

Instrumentação

Sistema por triangulação “sl-nose”



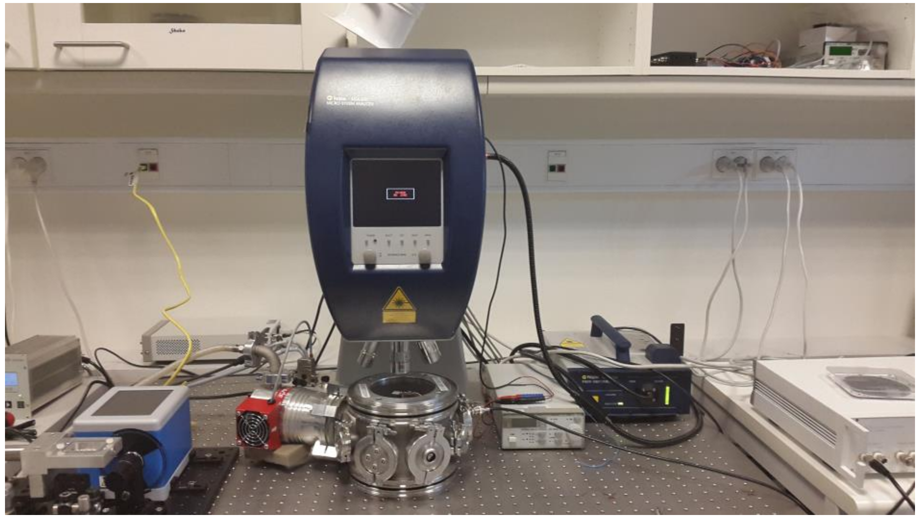
H.P. Lang et al, Handbook of Nanotechnology, Springer, pp. 427-452 (2010)

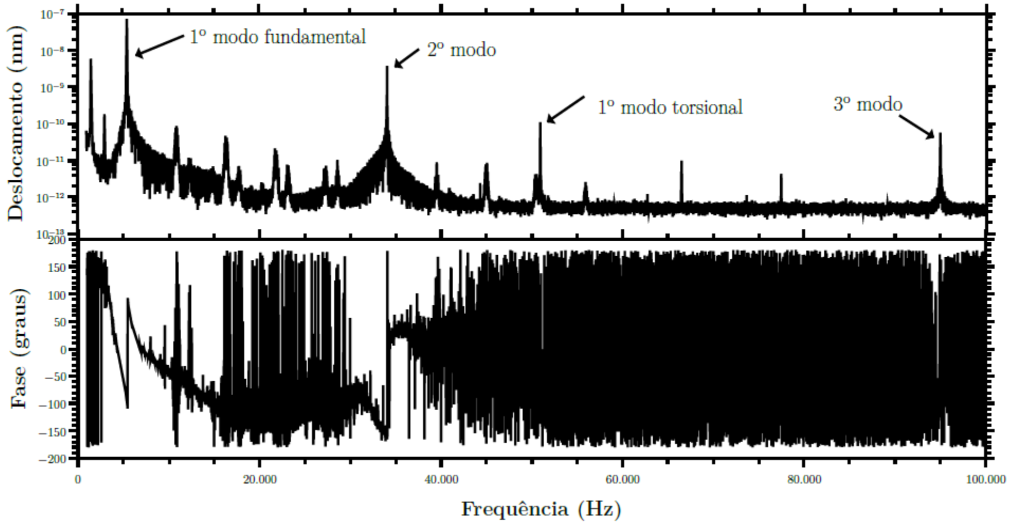


Instrumentação

Vibrômetro Laser Doppler –

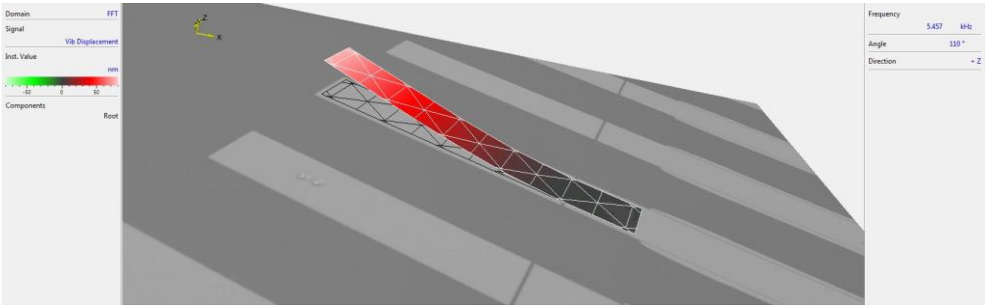
- Permite leitura de frequências de ressonância e modos de vibração.

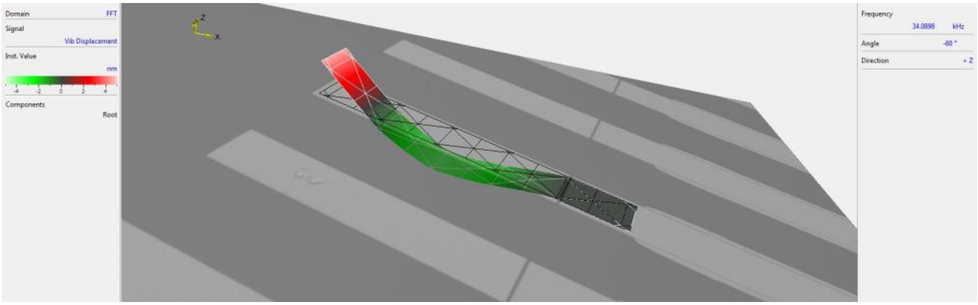


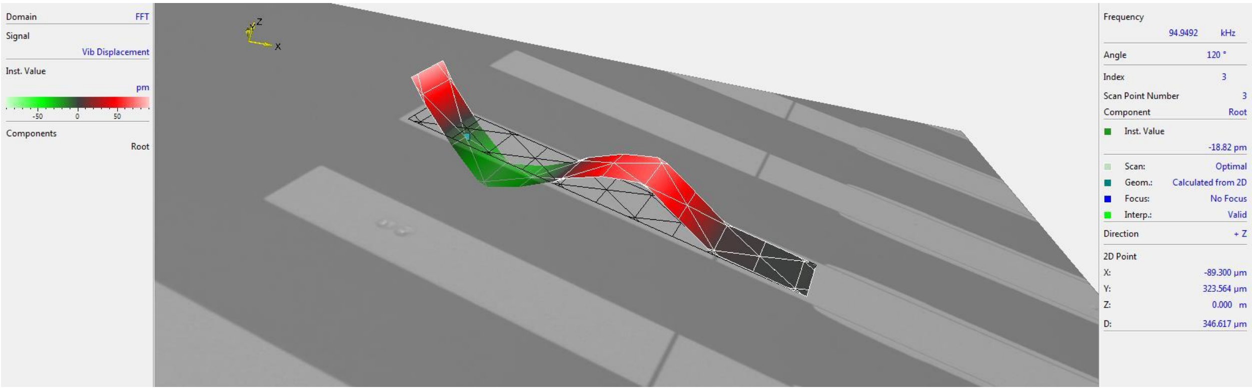


Instrumentação

Vibrômetro Laser Doppler



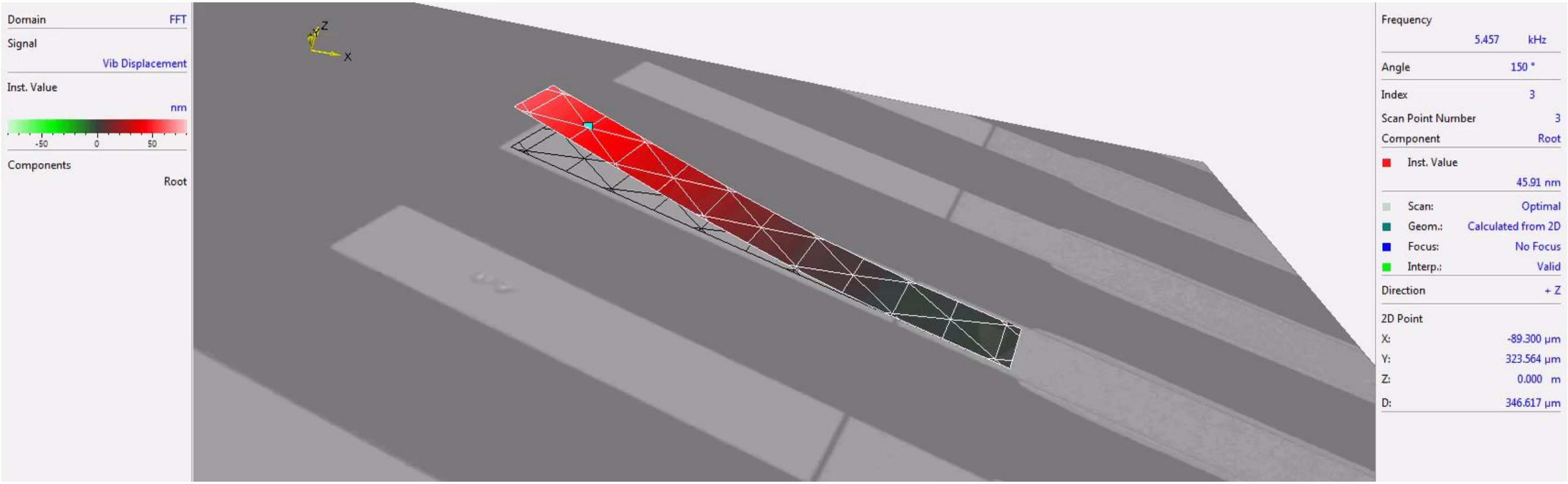




Instrumentação

Vibrômetro Laser Doppler

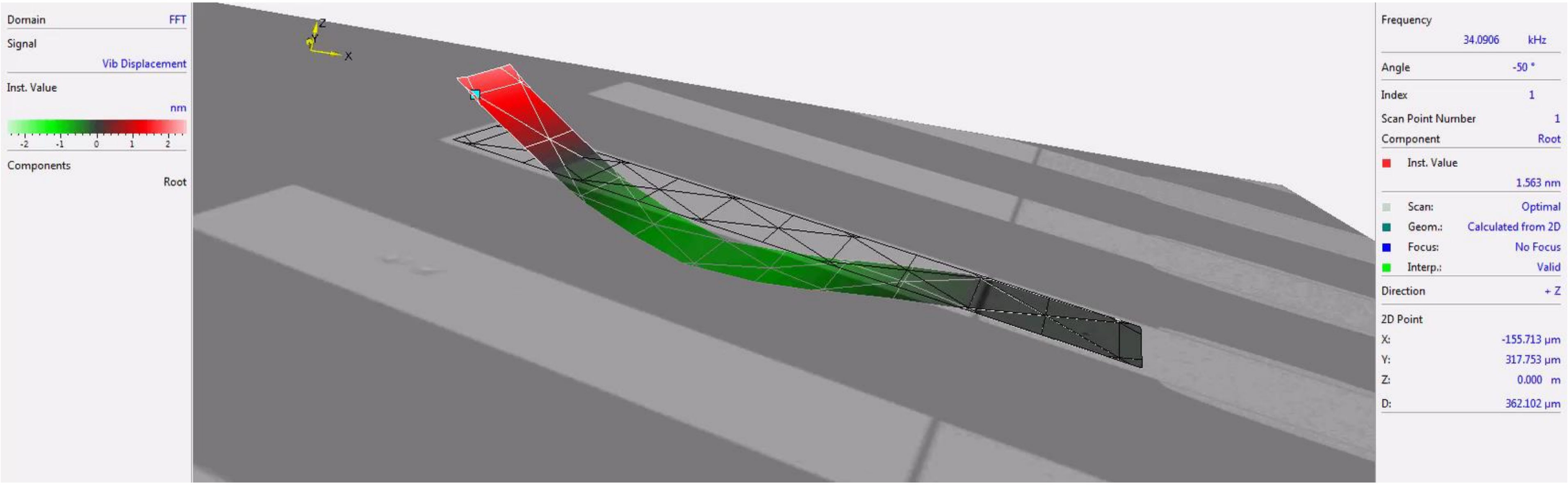
- Algumas medidas:



Instrumentação

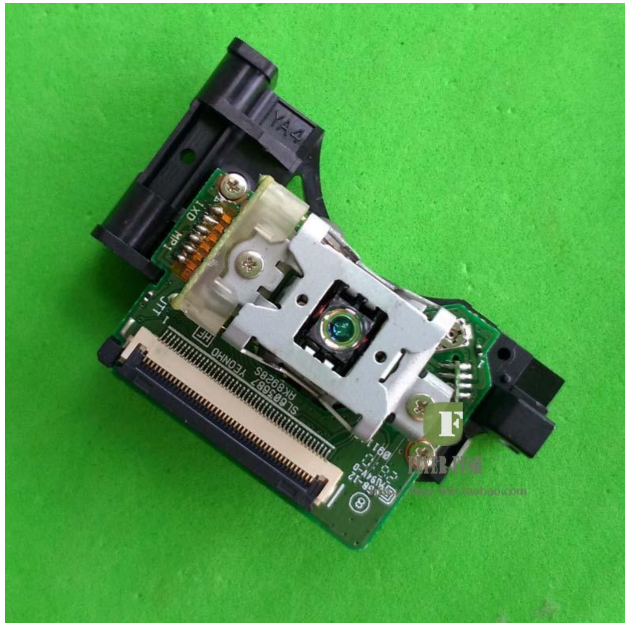
Vibrômetro Laser Doppler –

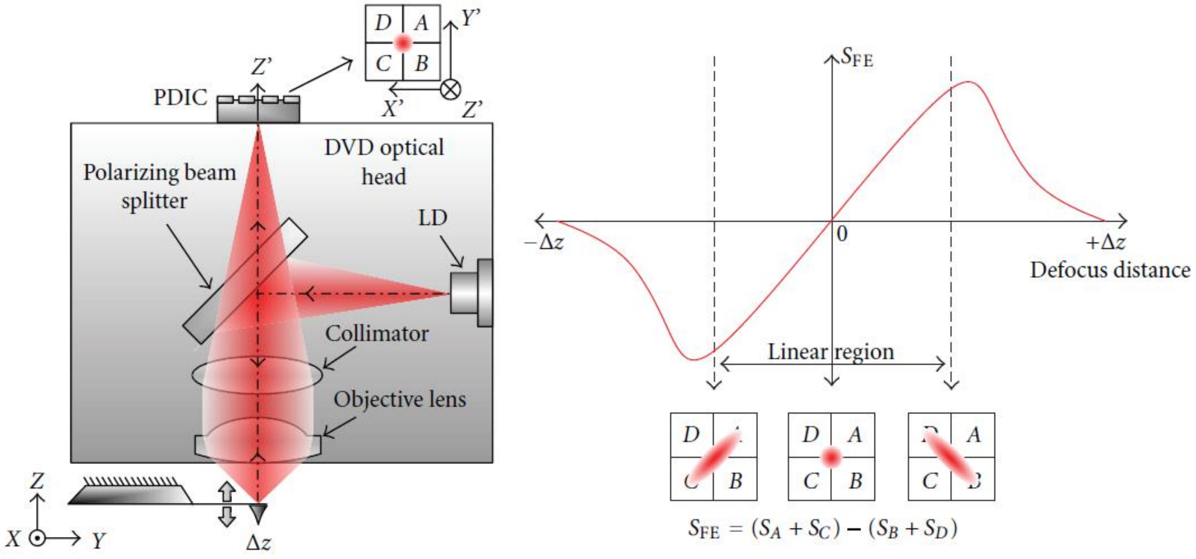
- Algumas medidas:



Instrumentação

Desenvolvimento de sistema para medida de dispositivo micromecânicos





(a) (b)

Research Article

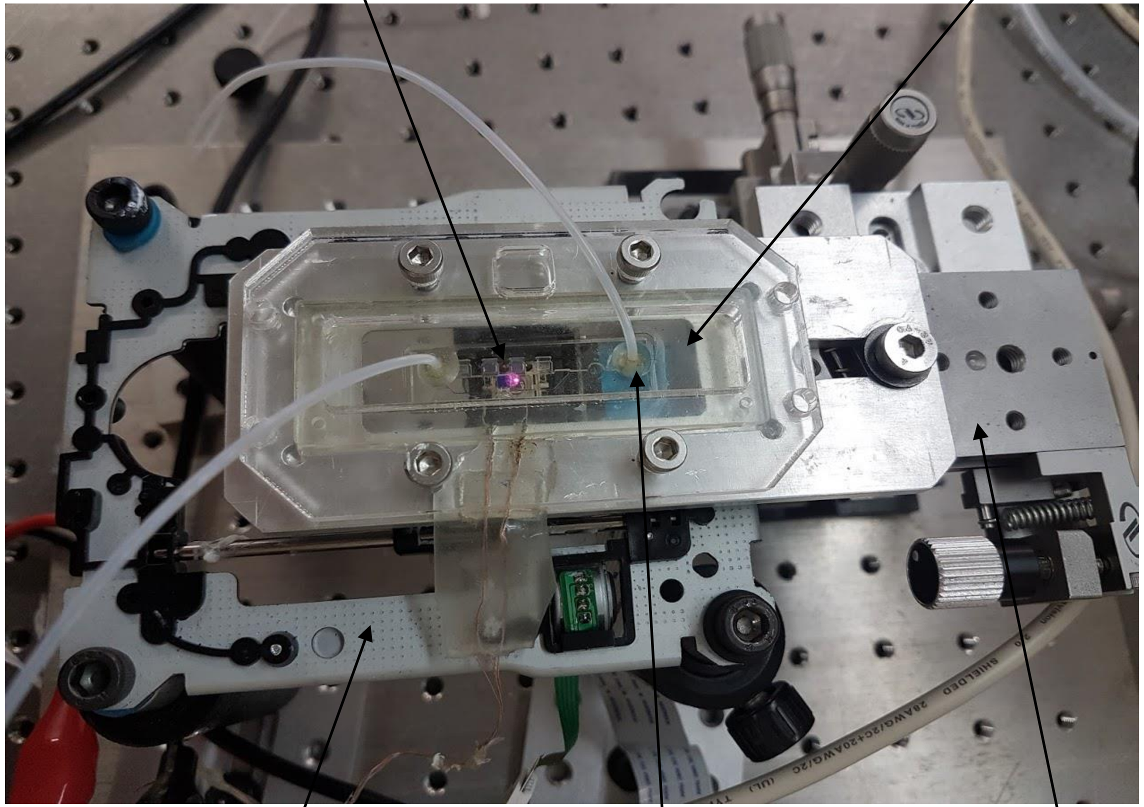
An Astigmatic Detection System for Polymeric Cantilever-Based Sensors

En-Te Hwu,[1] Hsien-Shun Liao,[1,2] Filippo G. Bosco,[3] Ching-Hsiu Chen,[1] Stephan Sylvest Keller,[3] Anja Boisen,[3] and Kuang-Yuh Huang[2]

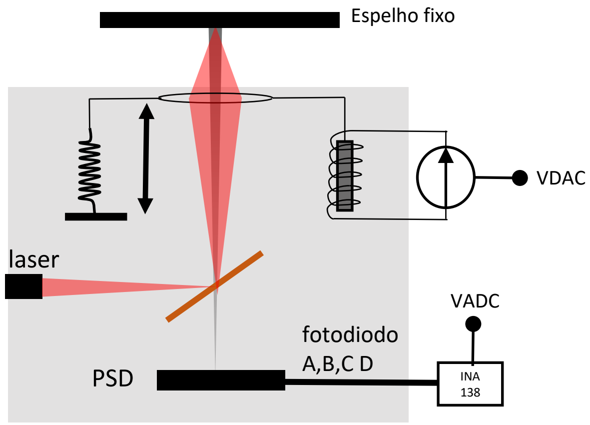
[1] Institute of Physics, Academia Sinica, Nankang, Taipei 11529, Taiwan
[2] Department of Mechanical Engineering, National Taiwan University, Taipei 10617, Taiwan
[3] Department of Micro- and Nanotechnology, Technical University of Denmark, 2800 Lyngby, Denmark

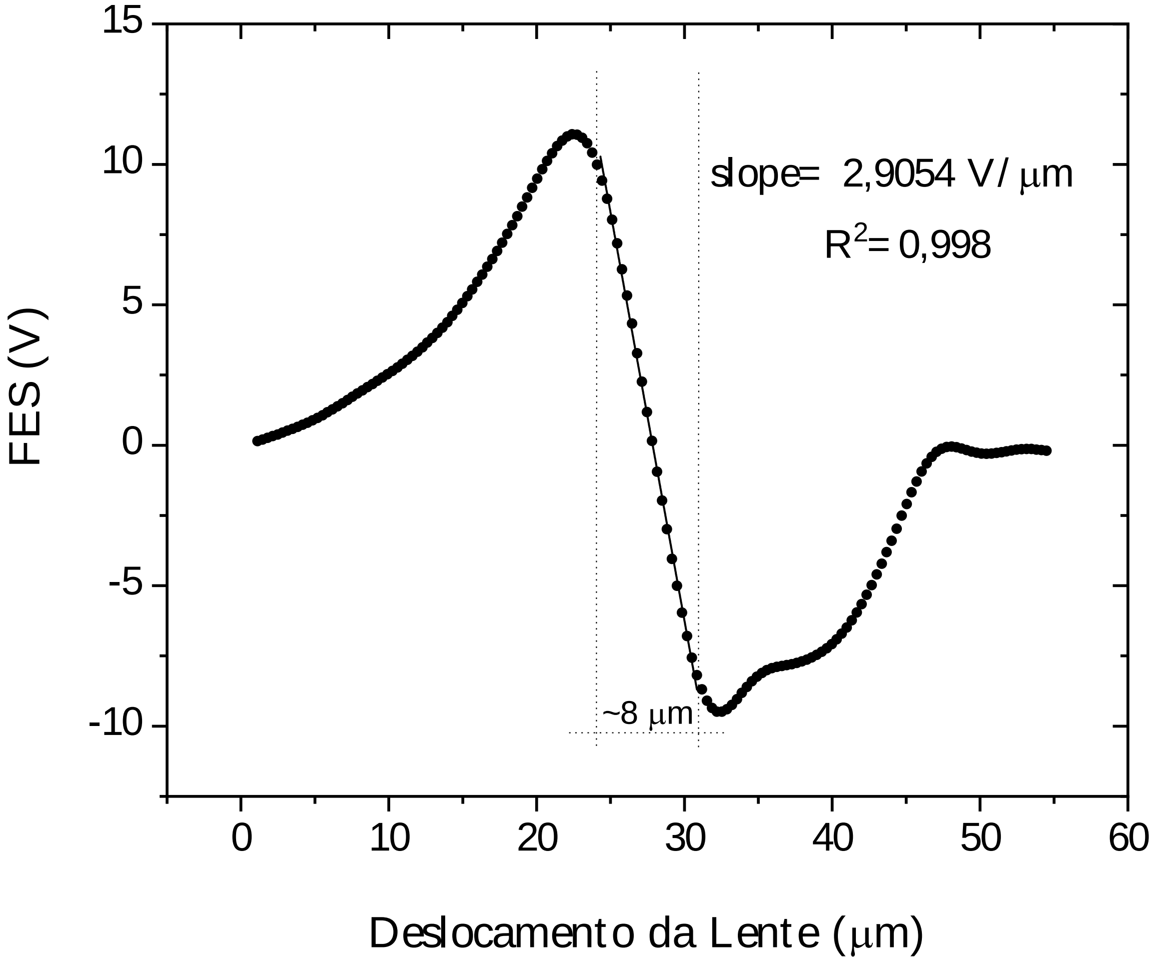
Correspondence should be addressed to En-Te Hwu, whoand@phys.sinica.edu.tw

Sistema de medidas

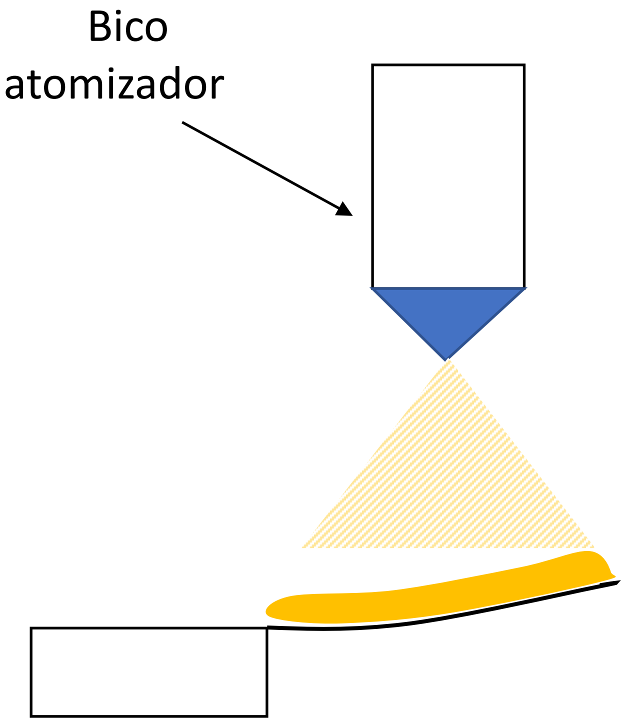


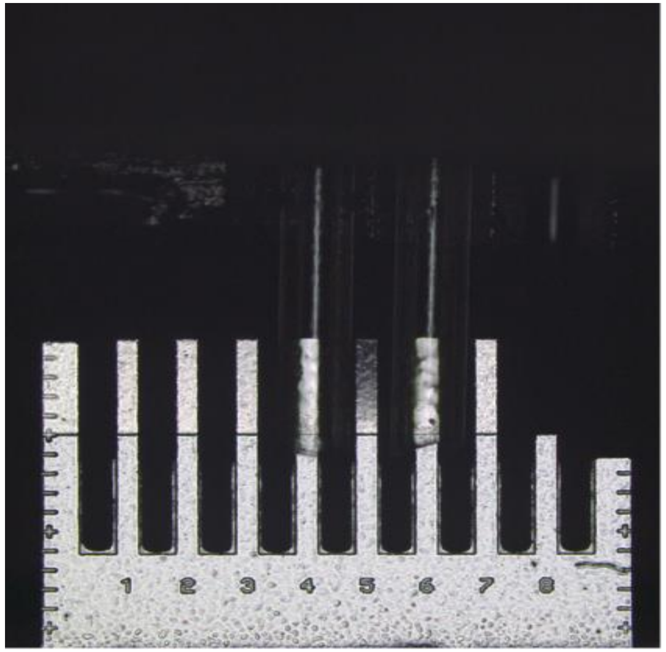
Medida da curva FES

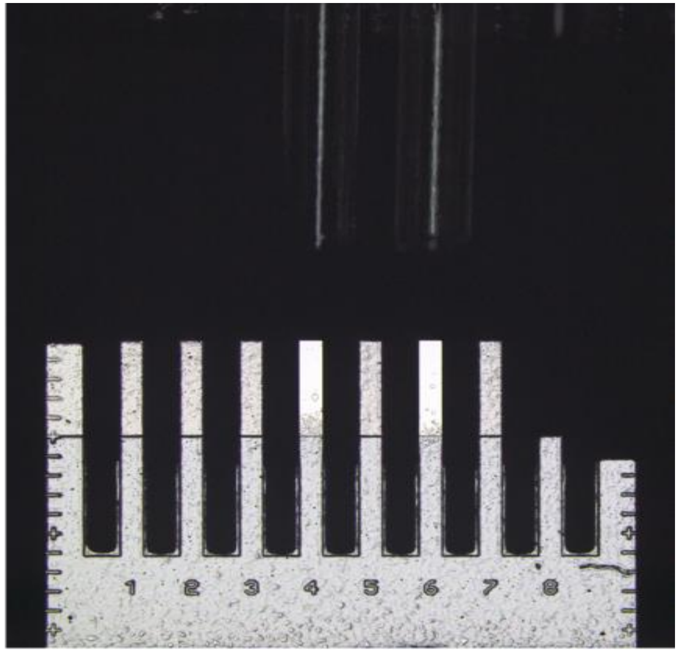




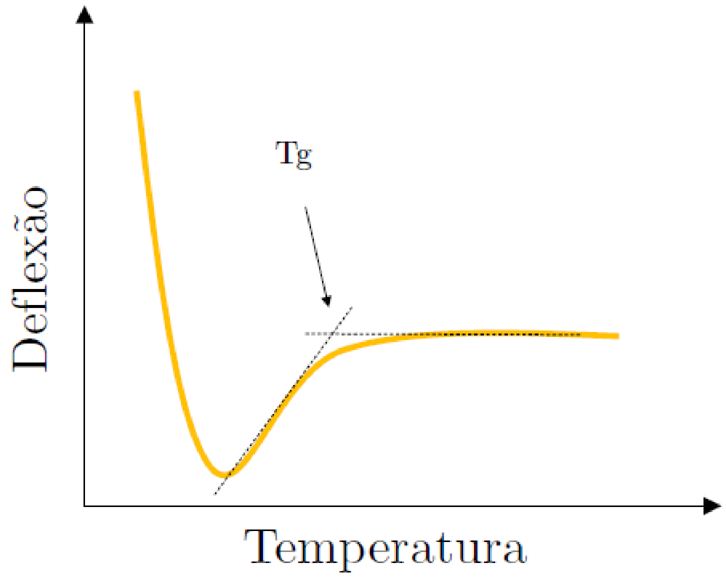
Deposição do PLGA sobre microcantilever

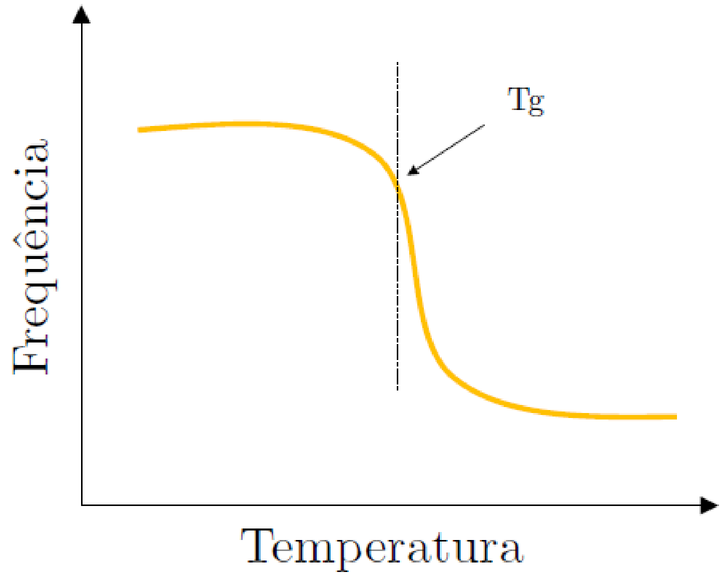


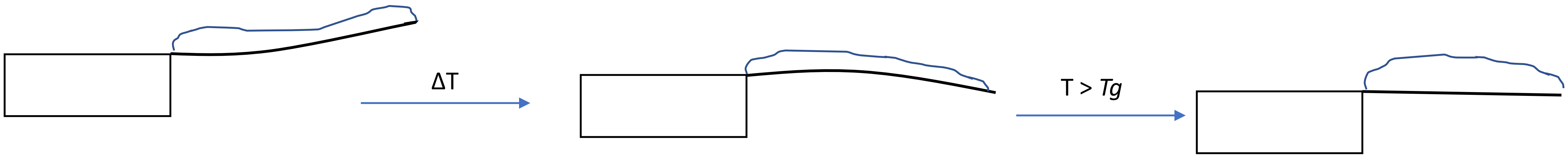




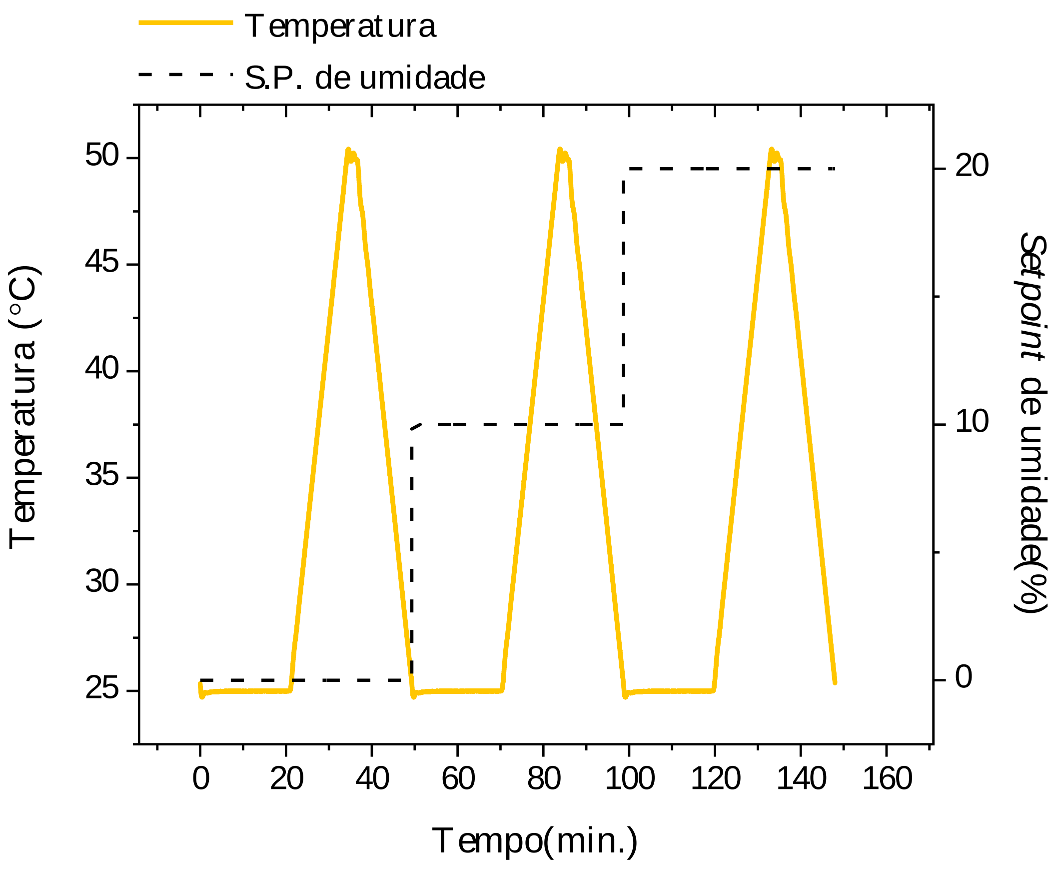
Caracterização térmica com microcantilever

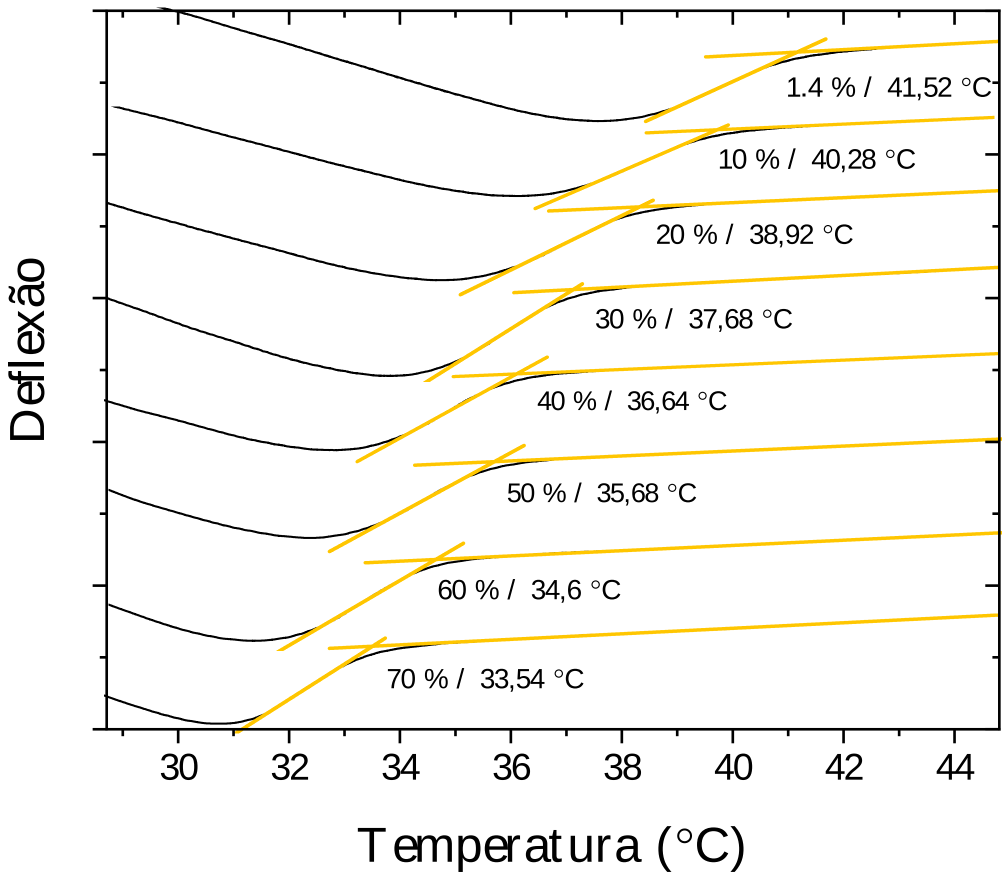




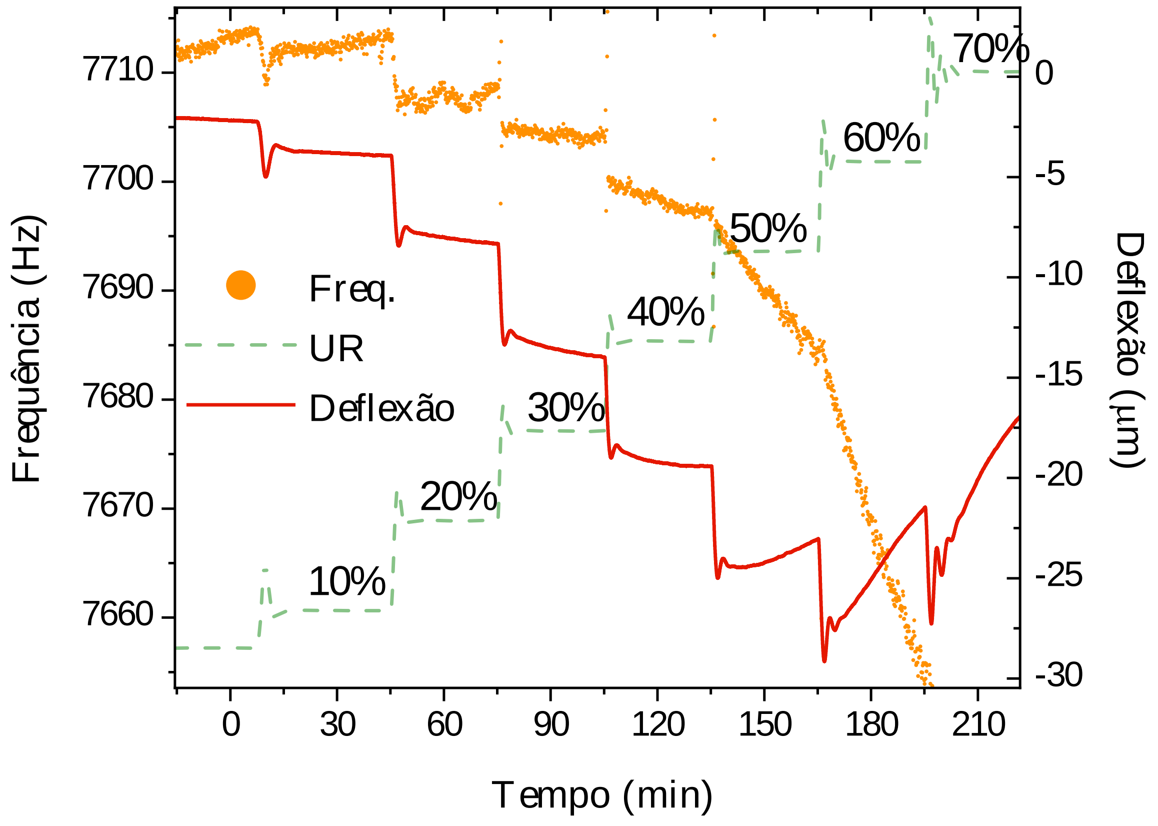


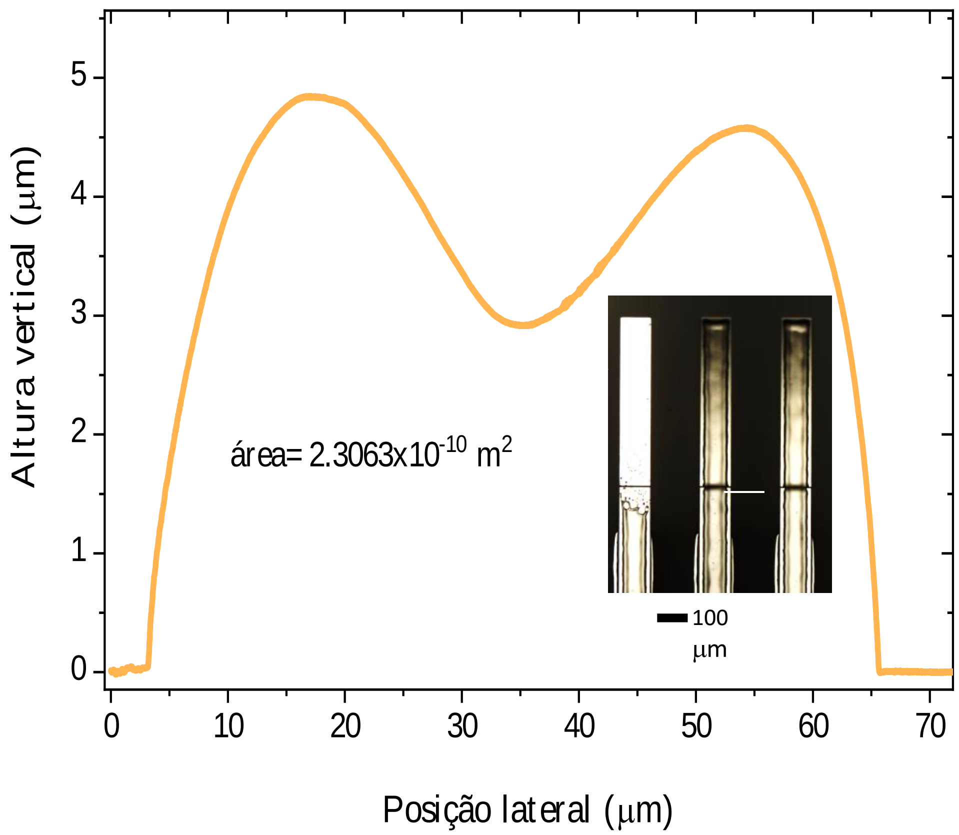
Tg versus umidade relativa



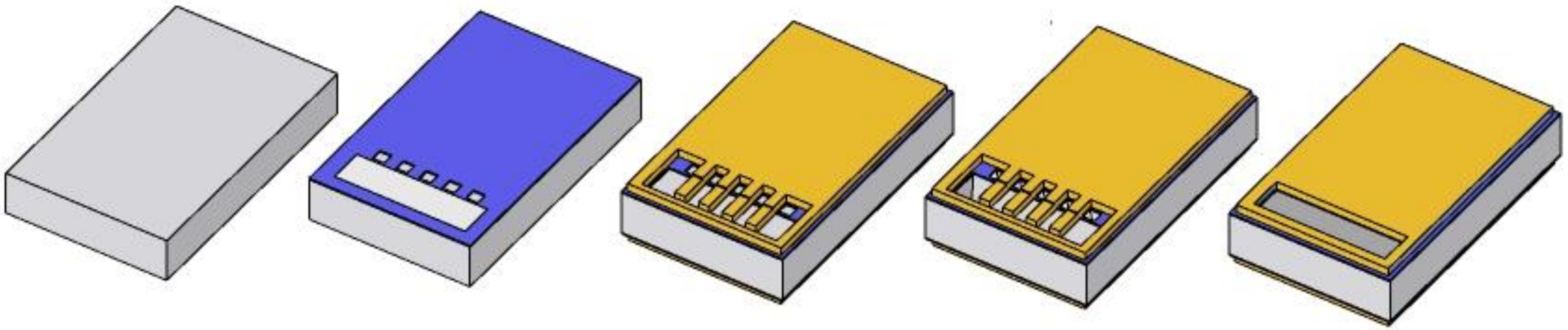


Medida da massa de água no polímero

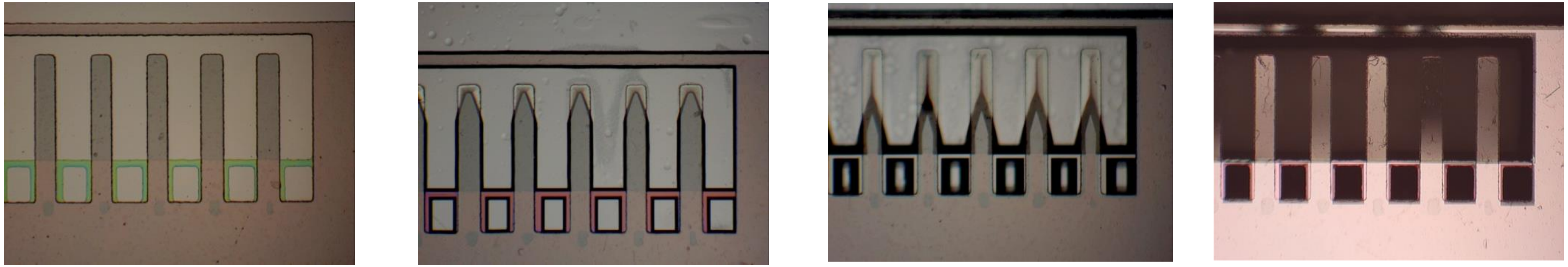




Fabricação de matrizes de cantileveres poliméricos

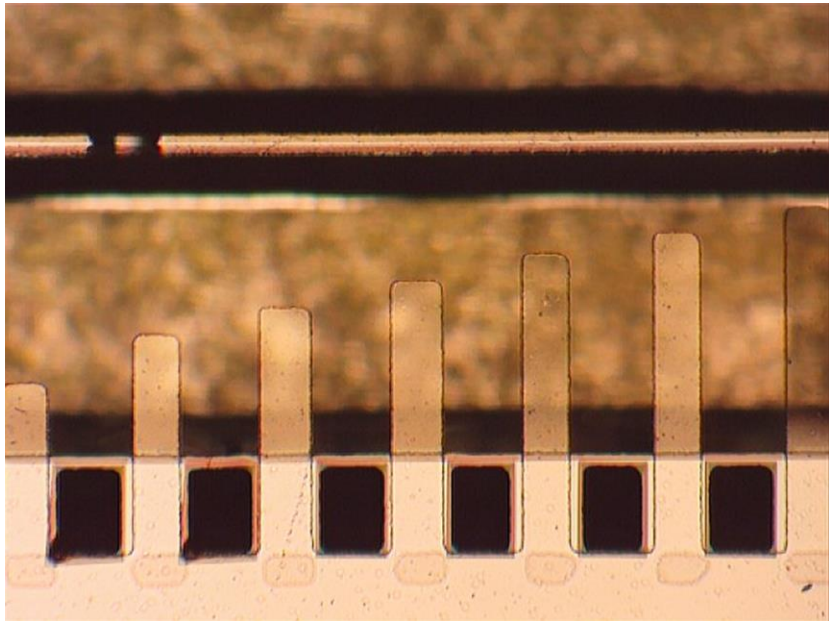


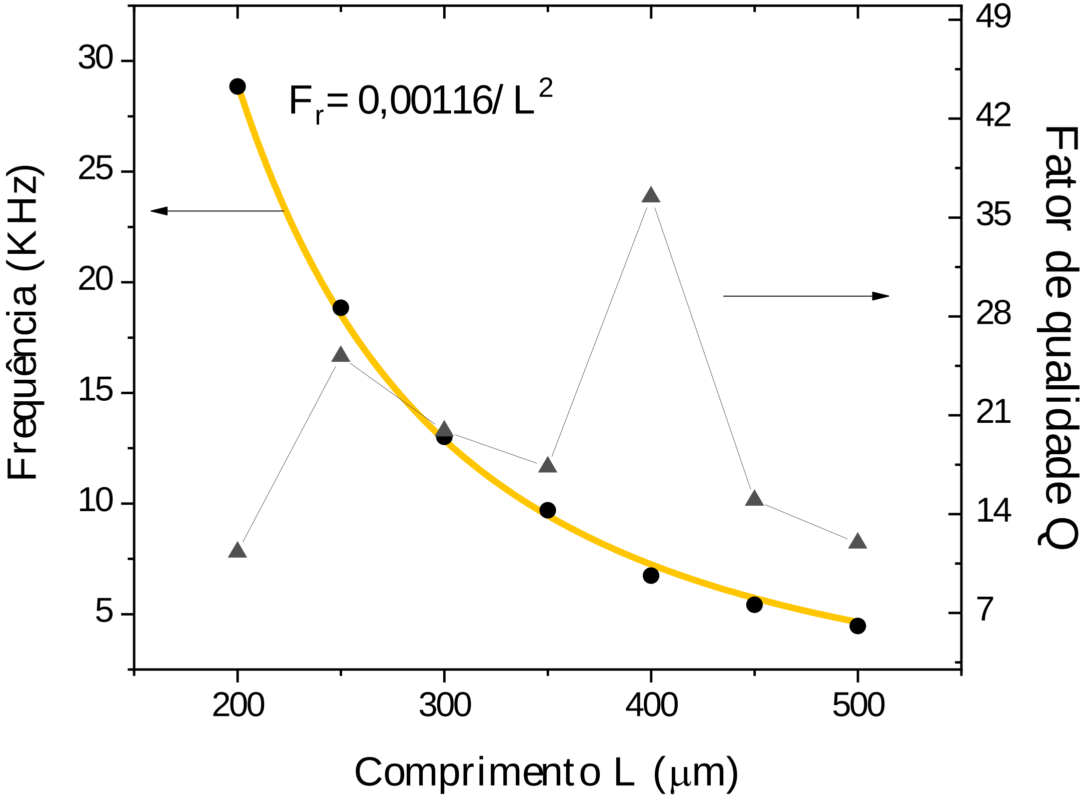
0 µm   26 µm   76 µm   190 µm



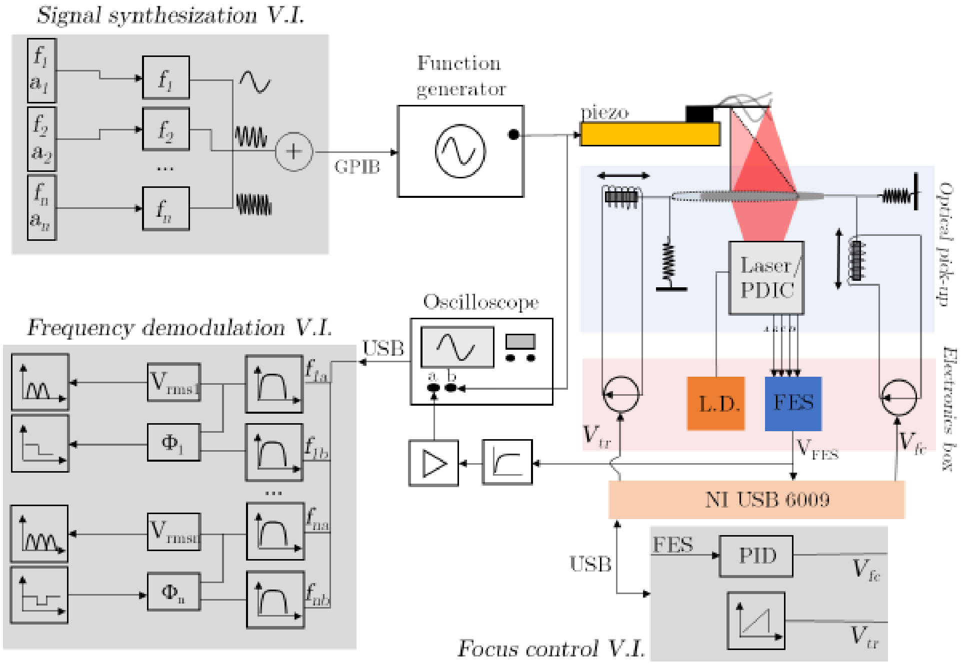
100 µm

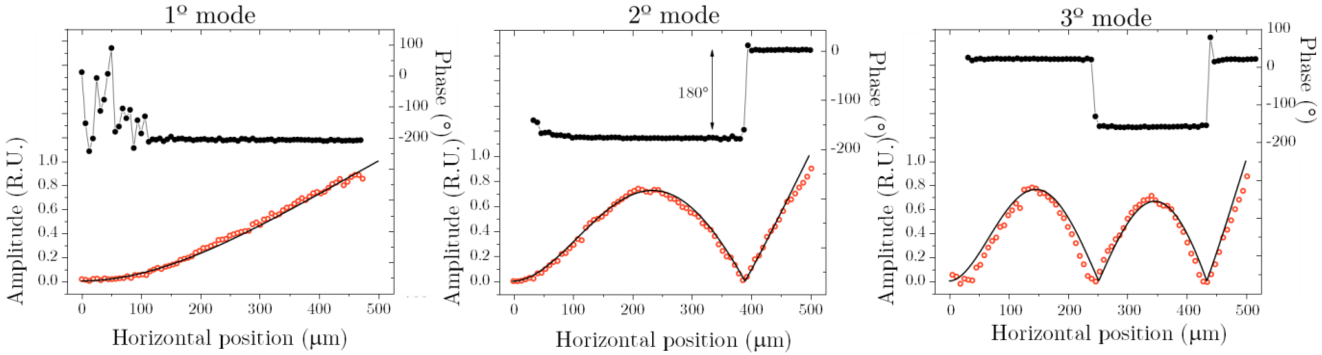
Caracterização dinâmica





Caracterização dos modos de vibração





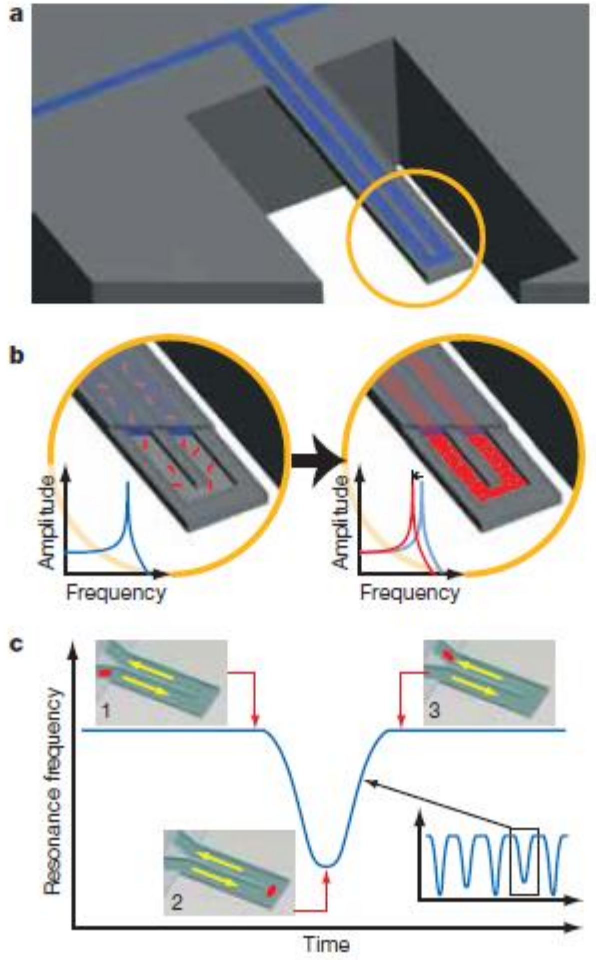
Estado da arte na literatura

nature Vol 446|26 April 2007|doi:10.1038/nature05741

LETTERS

Weighing of biomolecules, single cells and single nanoparticles in fluid

Thomas P. Burg[1]*, Michel Godin[1]*, Scott M. [illegible]dsen[1], Wenjiang Shen[3], Greg Carlson[3], John S. Foster[3], Ken Babcock[3,4] & Scott R. Manalis[1,2]



Estado da arte na literatura

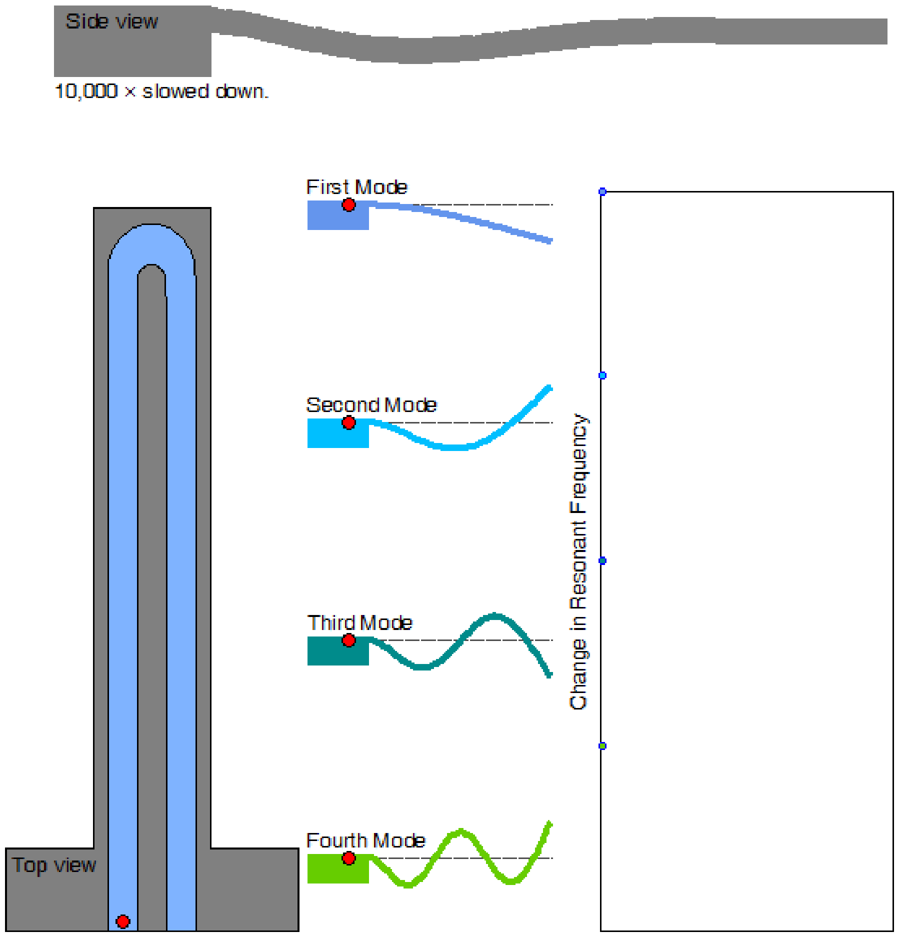
nature COMMUNICATIONS

ARTICLE

Received 25 Nov 2014 | Accepted 28 Mar 2015 | Published 12 May 2015 DOI: 10.1038/ncomms8070 OPEN

High-speed multiple-mode mass-sensing resolves dynamic nanoscale mass distributions

Selim Olcum[1,*], Nathan Cermak[2,*], Steven C. Wasserman[3] & Scott R. Manalis[1,2,3,4]



Estado da arte na literatura

Sensors and Actuators B 233 (2016) 667–673

Contents lists available at ScienceDirect

Sensors and Actuators B: Chemical

journal homepage: www.elsevier.com/locate/snb

Nanomechanical IR spectroscopy for fast analysis of liquid-dispersed engineered nanomaterials

Alina J. Andersen [*,1], Shoko Yamada [1], E.K. Pramodkumar, Thomas L. Andresen, Anja Boisen, Silvan Schmid

Department of Micro- and Nanotechnology, Technical University of Denmark, DTU Nanotech, DK-2800 Kgs. Lyngby, Denmark

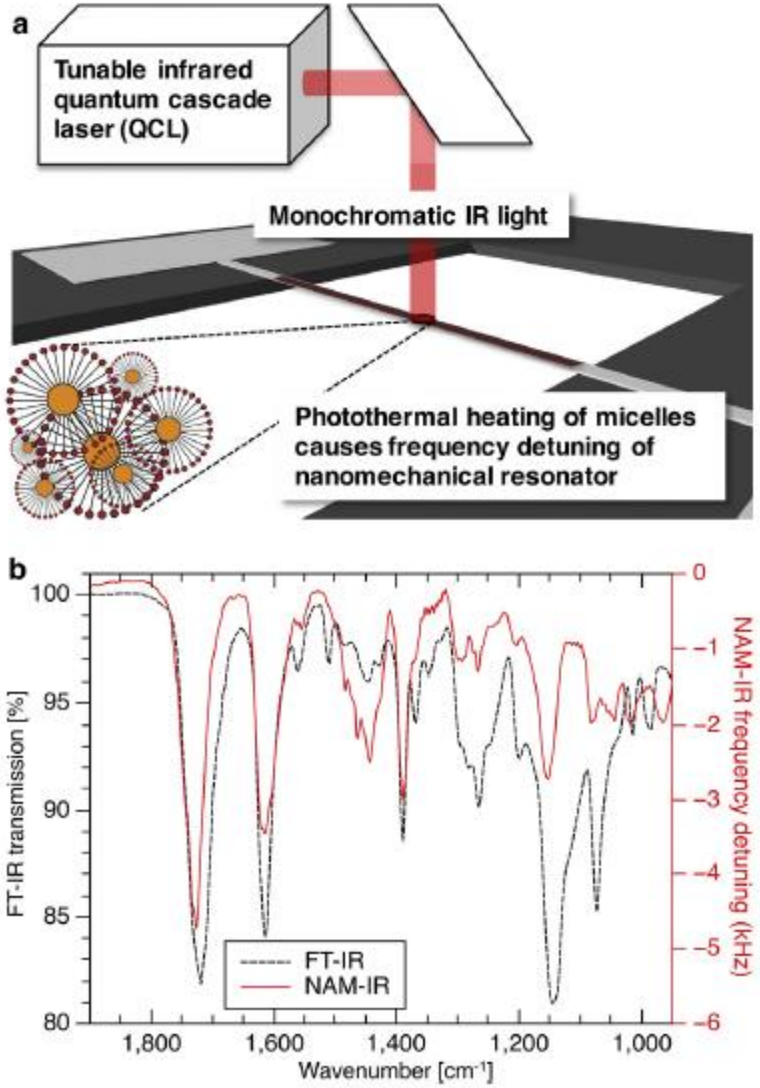


Fig. 7. (a) Schematic drawing of the NAM-IR method. The micelles collected on the

Estado da arte na literatura

nature COMMUNICATIONS

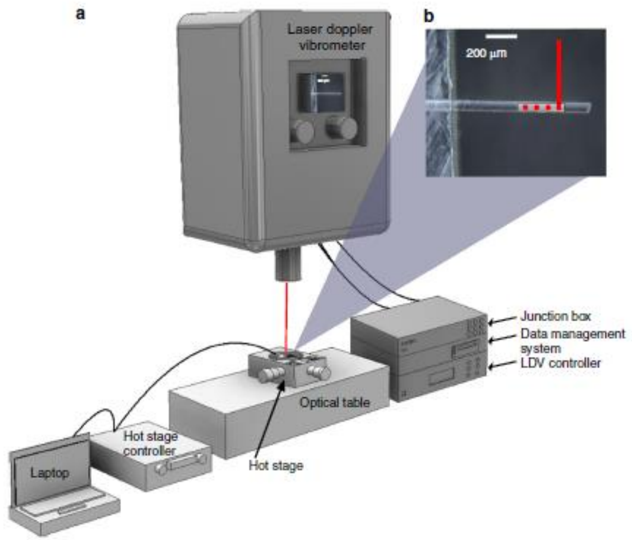
ARTICLE

Check for updates

https://doi.org/10.1038/s41467-020-15028-y OPEN

Single particles as resonators for thermomechanical analysis

Peter Ouma Okeyo[1,2,3✉], Peter Emil Larsen[2,3], Eric Ofosu Kissi[4], Fatemeh Ajalloueian[2,3], Thomas Rades[1], Jukka Rantanen[1] & Anja Boisen[2,3✉]



A schematic and operation. a Schematic representation of the measurement setup for PMTA where the junction box, data mana
oppler vibrometer (LDV) controller are used for operating and managing the data generated from the LDV. b Optical image of a s
e monohydrate (TP MH) used as a cantilever with a laser spot on top (red) from the LDV as well as a measurement grid wit
red spots) that are defined using the LDV software. The particle is mounted on a 5 mm × 5 mm aluminium block (left side of the
lectric crystal was placed adjacent to the aluminium block during the measurements.

Estado da arte na literatura

nature COMMUNICATIONS

ARTICLE

Received 9 Jan 2015 | Accepted 2 Feb 2015 | Published 10 Mar 2015 DOI: 10.1038/ncomms7482 OPEN

Neutral particle mass spectrometry with nanomechanical systems

Eric Sage[1,2], Ariel Brenac[3,4], Thomas Alava[1,2], Robert Morel[3,4], Cécilia Dupré[1,2], Mehmet Selim Hanay[5,†], Michael L. Roukes[5], Laurent Duraffourg[1,2], Christophe Masselon[1,6,7] & Sébastien Hentz[1,2]

established MS system. This lack of comparison probably stems from the fact that NEMS operate in a mass range where there is no accepted mass standard (i.e., the atomic or molecular calibrants used in MS[23,24]). Furthermore, NEMS-MS has an

and readily condenses into large clusters. The cluster po generated follow a log normal distribution law with mea of up to 4.5 MDa (diameter up to 9.5 nm). The T NEMS-MS mass spectra acquired for various populati

a b

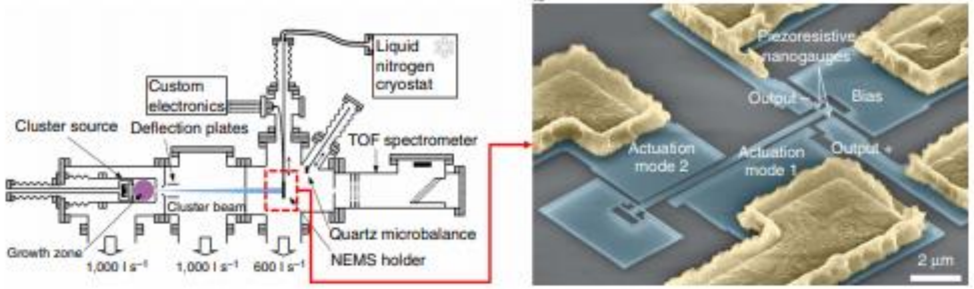


Figure 1 | Hybrid setup for TOF-MS and NEMS-MS of nanoparticles. (**a**) Diagram showing the full setup from left to right: the cluster sour intermediate chamber comprising deflection plates, the deposition chamber and an in-line TOF mass spectrometer. Both NEMS holder and Q retractable, making sequential NEMS-MS, TOF-MS and QCM measurements possible in identical operating conditions. (**b**) Colourized scannin microscope image of a typical doubly clamped in-plane resonator used in this study. The beams were designed to resonate around 25 MHz for m

Obrigado pela atenção