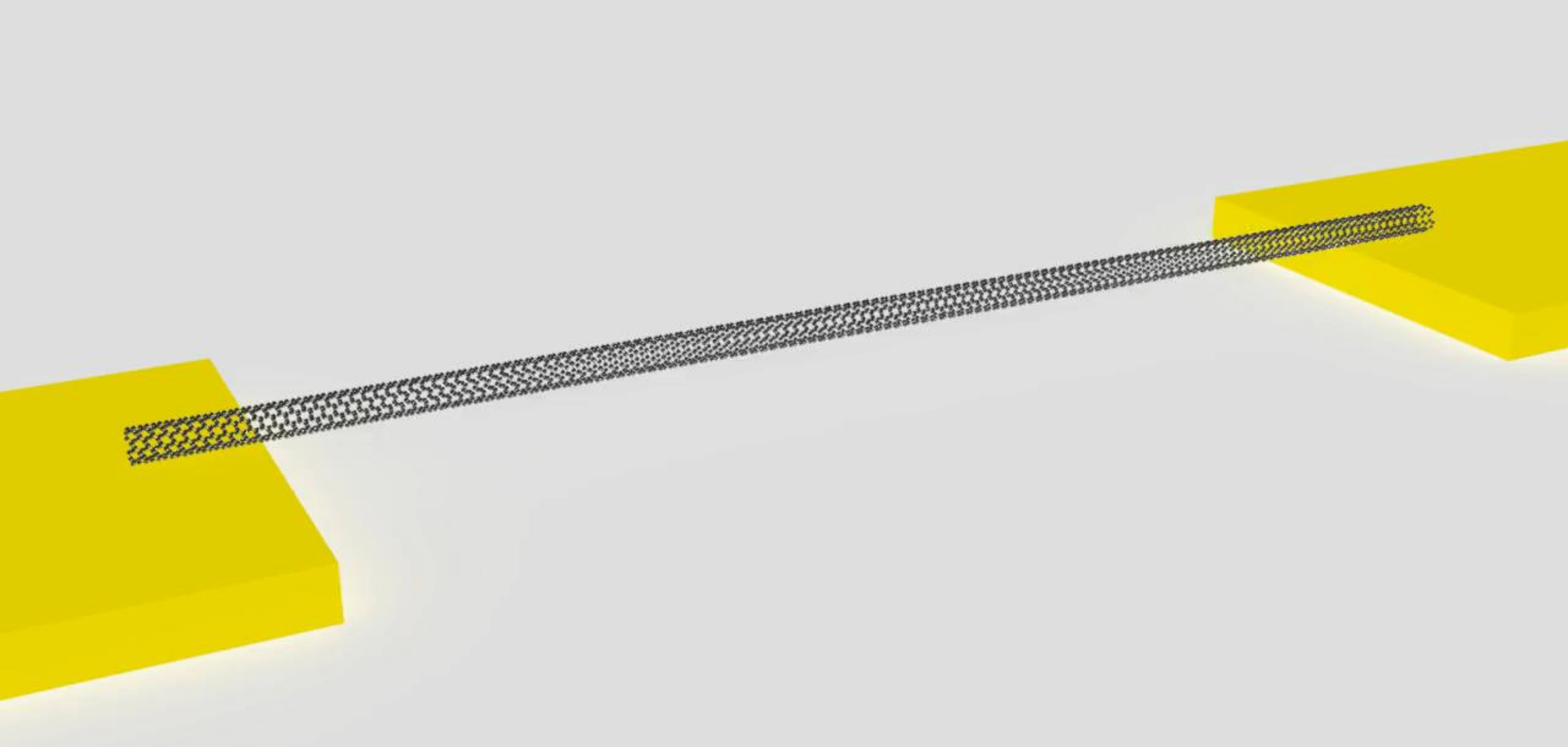
video of Slaven Tepsic



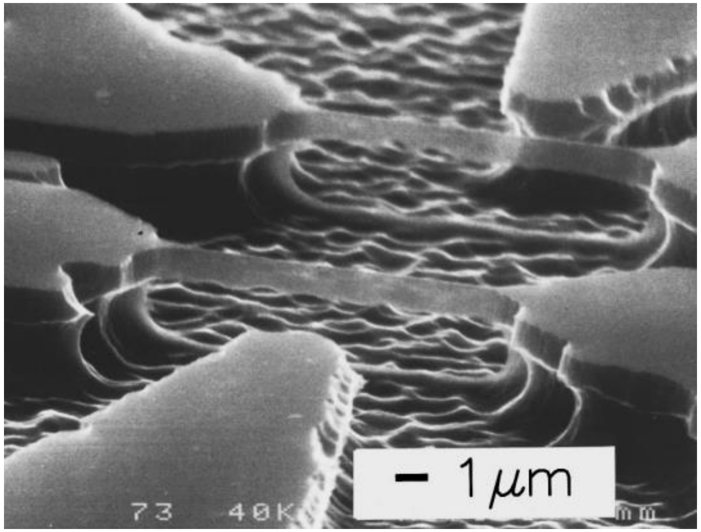
Quantum NanoMechanics group
Adrian Bachtold – ICFO

Generalitat de Catalunya
GOBIERNO DE ESPAÑA
GRAPHENE FLAGSHIP
erc
EXCELENCIA SEVERO OCHOA
ICFO

Clean room @ icfo

Johann Osmond

why nanomechanics?



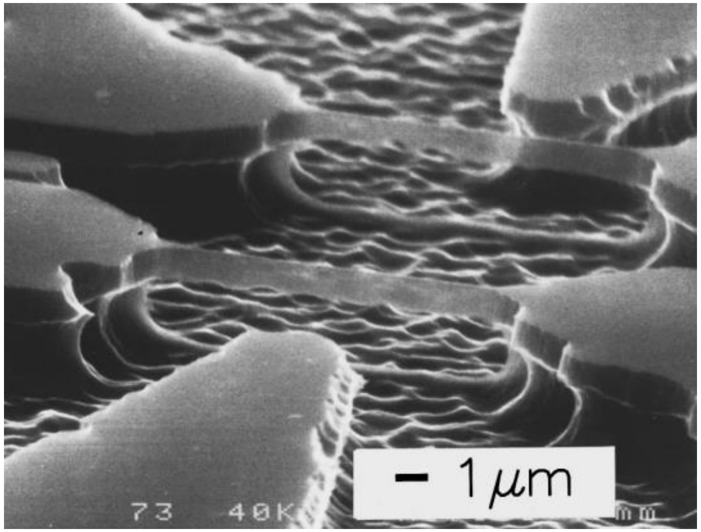
Cleland, Roukes, APL 1996

quantum

sensing

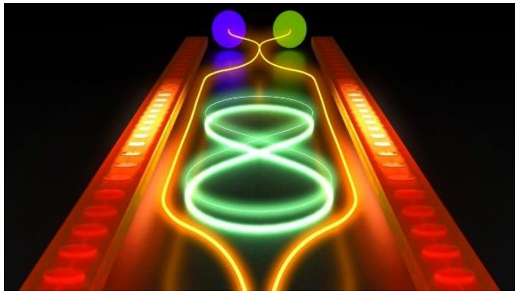
clocks

why nanomechanics?



Cleland, Roukes, APL 1996

Gröblacher



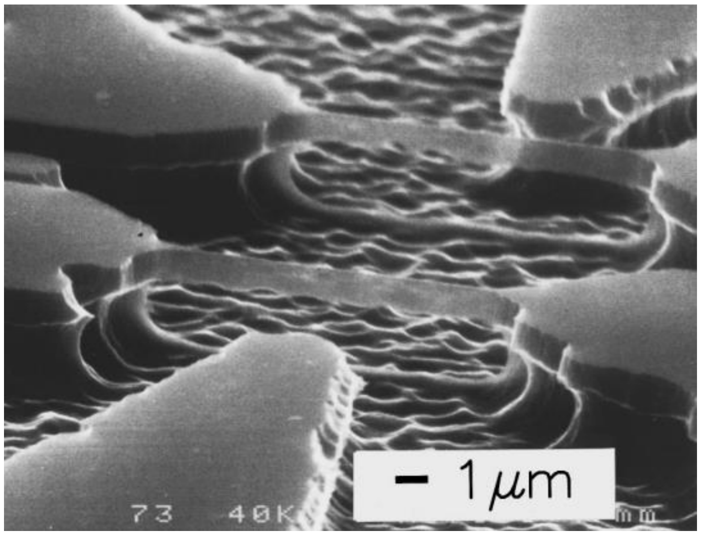
quantum experiment

sensing

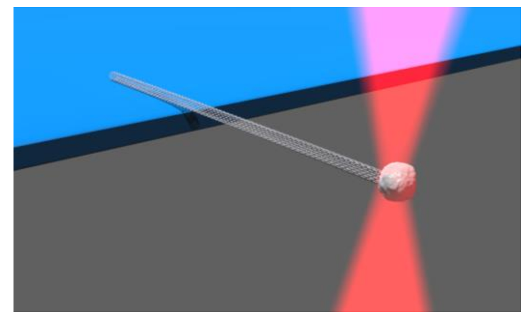
clocks

why nanomechanics?

quantum



Cleland, Roukes, APL 1996

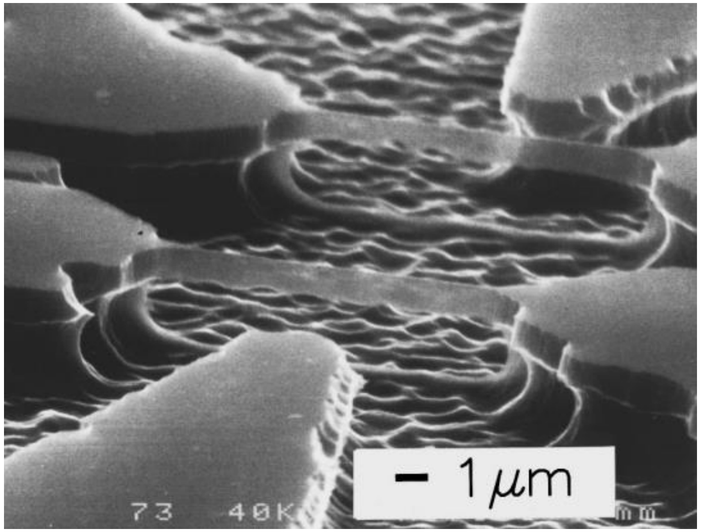


sensing at the ultimate limits

clocks

why nanomechanics?

quantum



Cleland, Roukes, APL 1996

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why nanomechanics?

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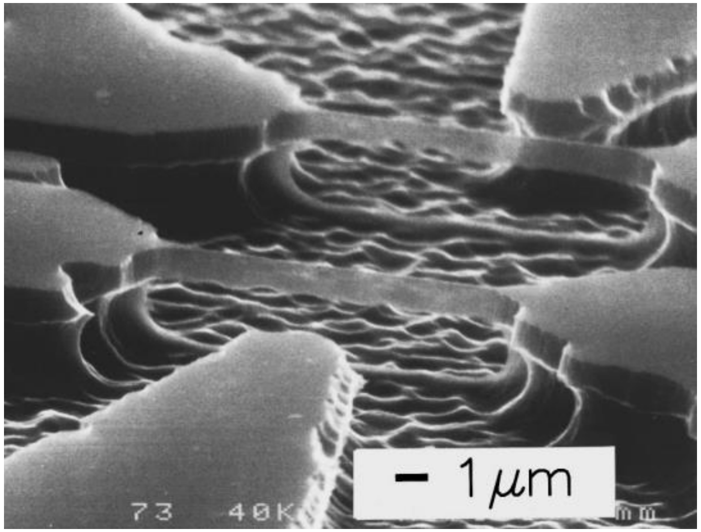


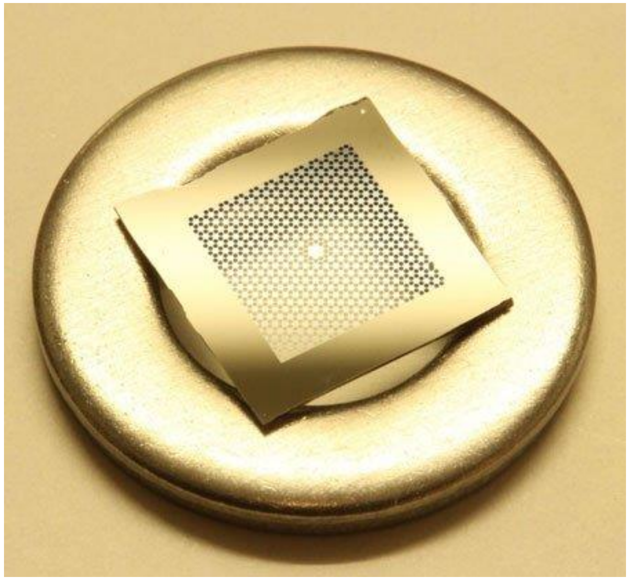
Cleland, Roukes, APL 1996

sensing

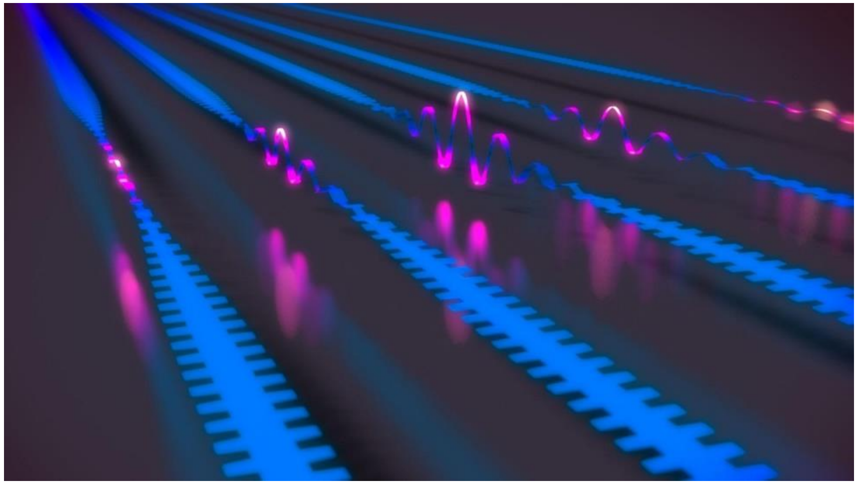
clocks

nonlinear physics
fluctuations
coupling vibrations to photons, electrons, spin, phonons …

Key is the ultra long life time



Schliesser - Polzik

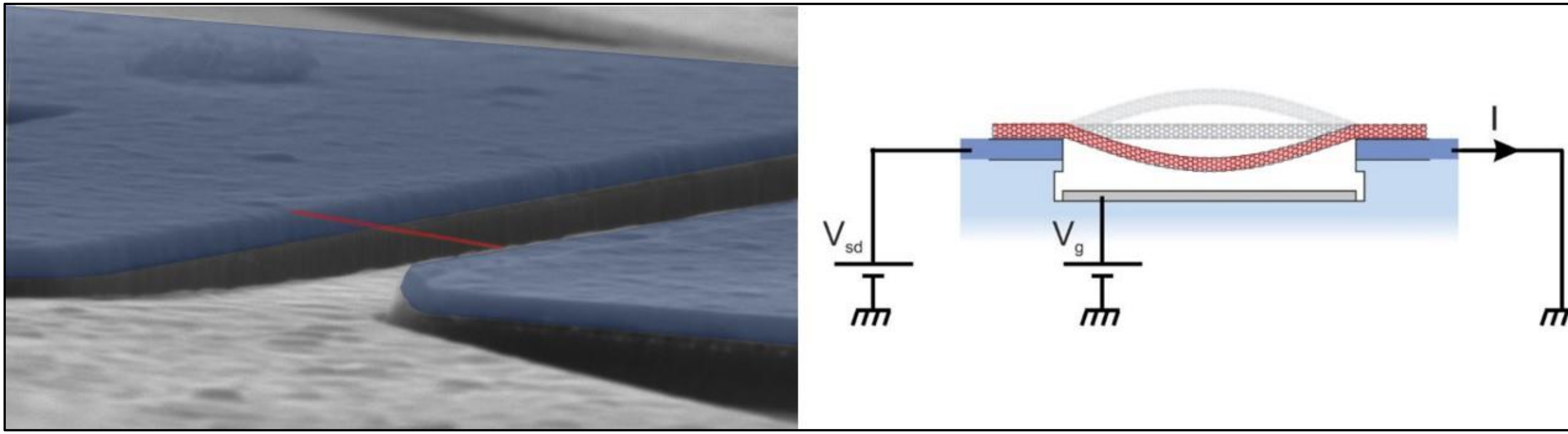


Kippenberg

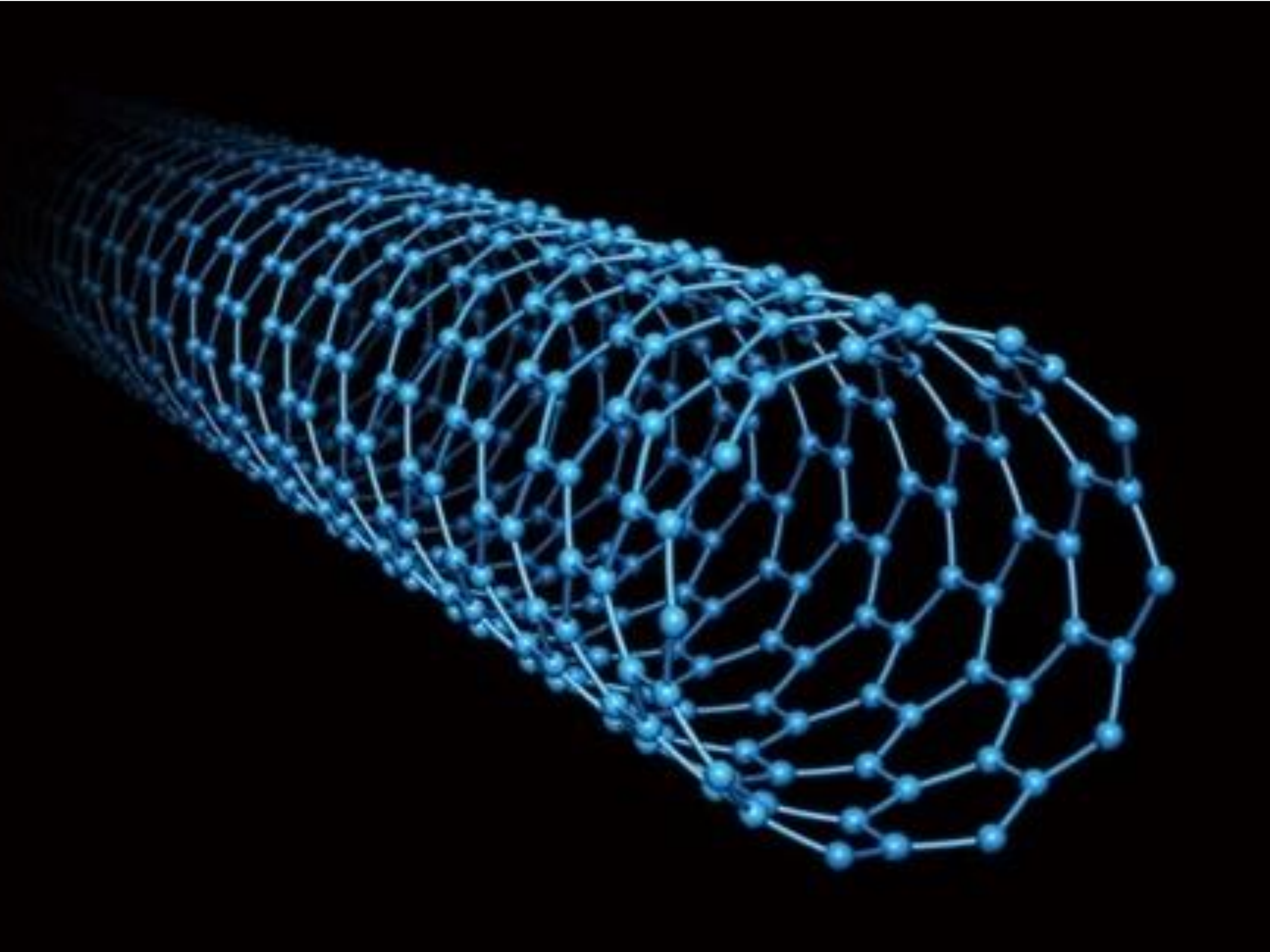
$\tau > 1$ minute

$Q > 100$ million

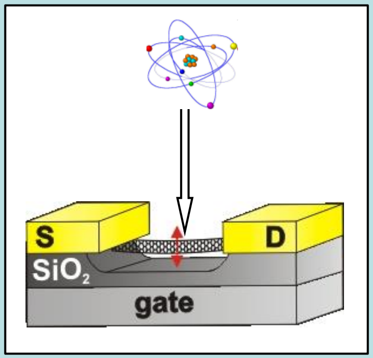
We like nanotube resonators



$Q \sim 10$ million



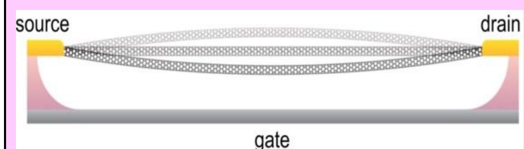
Mass sensing



1.7 yg

Chaste et al.,
Nature Nano (2012)

Force sensing

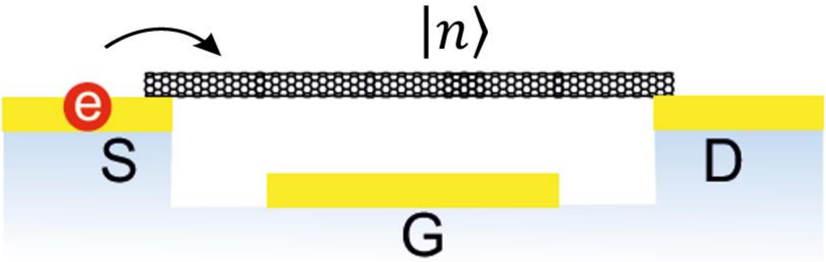


$\sim 1\,\mathrm{zN} \cdot \mathrm{Hz}^{-0.5}$

Moser, Güttinger, et al.,
Nature Nano (2013)
Moser, Eichler, et al.,
Nature Nano (2014)
de Bonis, Urgell, et al.
Nano Letters (2018)

"giant" zero-point motion amplitude

$$z_{zpm} = \sqrt{\frac{\hbar}{2\boldsymbol{m}\omega_0}} \sim 10\ \mathrm{pm}$$



$$n = 0\ or\ 1$$

$$g_0 = \frac{F z_{zpm}}{\hbar}$$

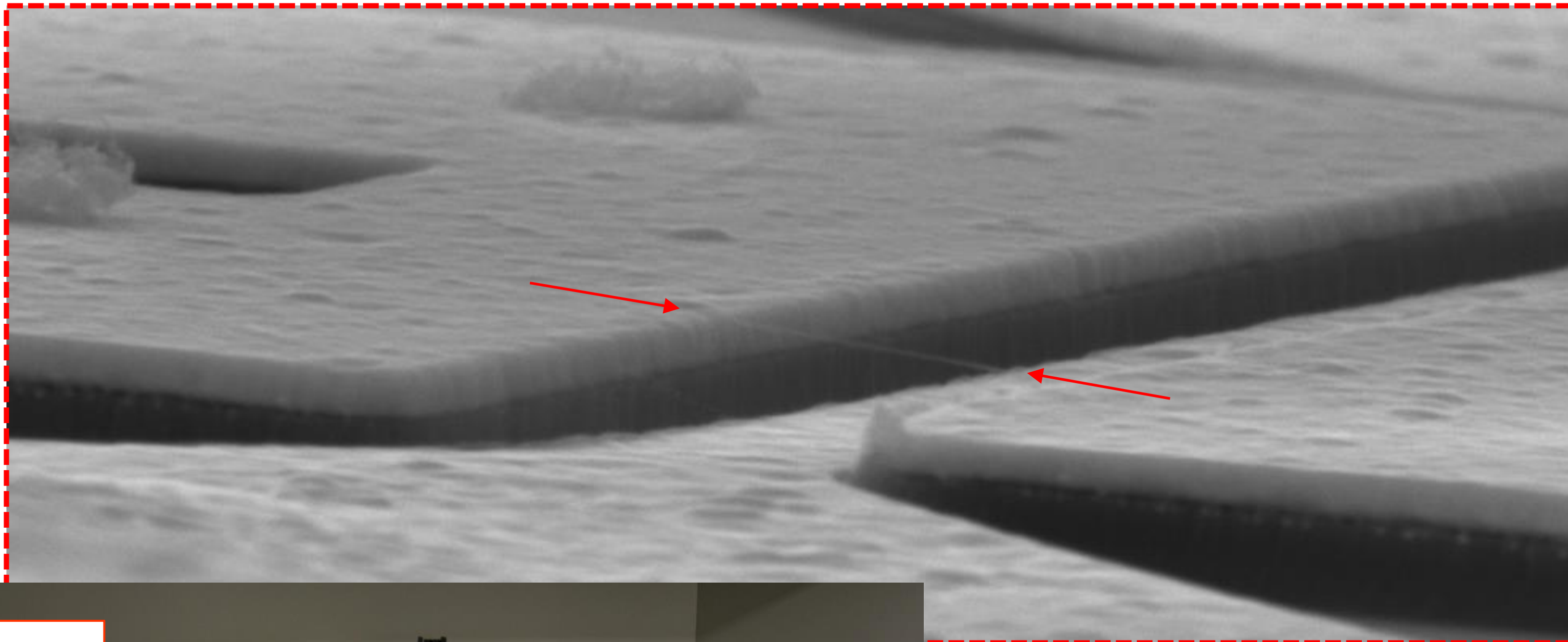
$$g_0 = 2\pi \cdot 348\mathrm{MHz}$$

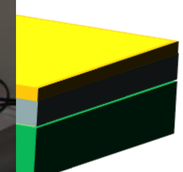
$$\omega_m = 2\pi \cdot 35.1\ \mathrm{MHz}$$

(unpublished)

$$H_i = Fzn = \hbar g_0 (a^+ + a)n$$

nanotube resonator

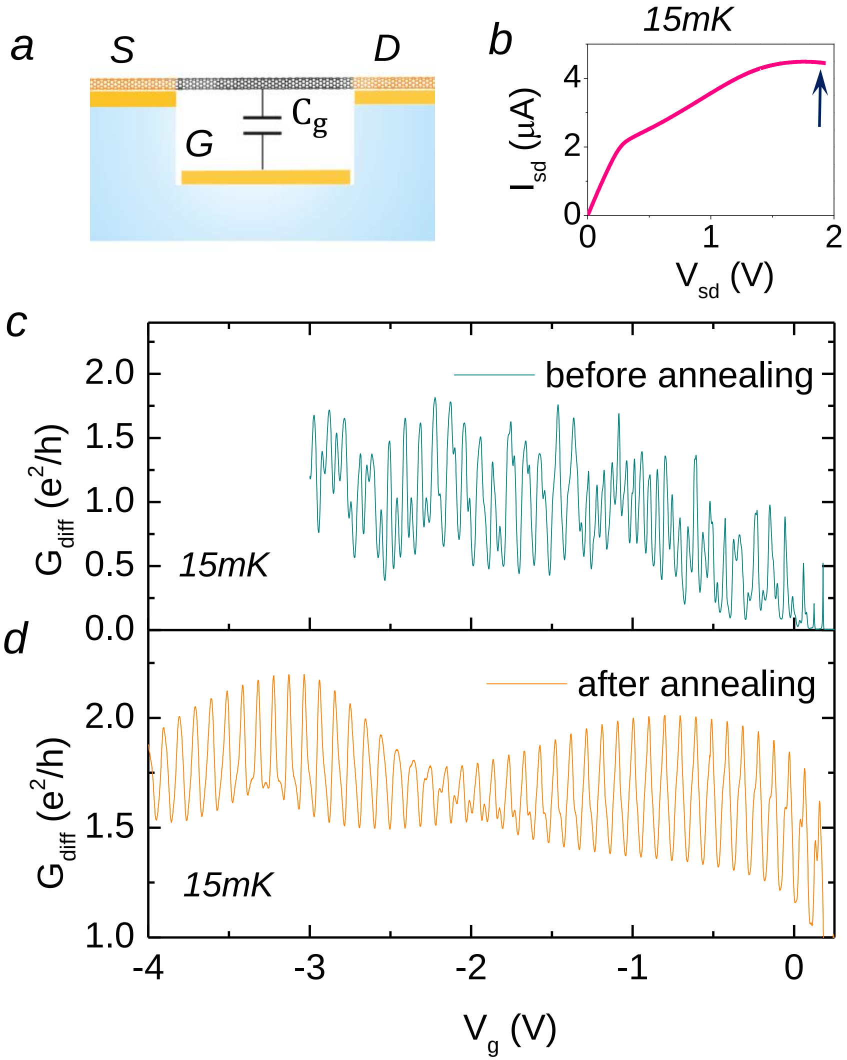




et al., Nano Letters (2018)

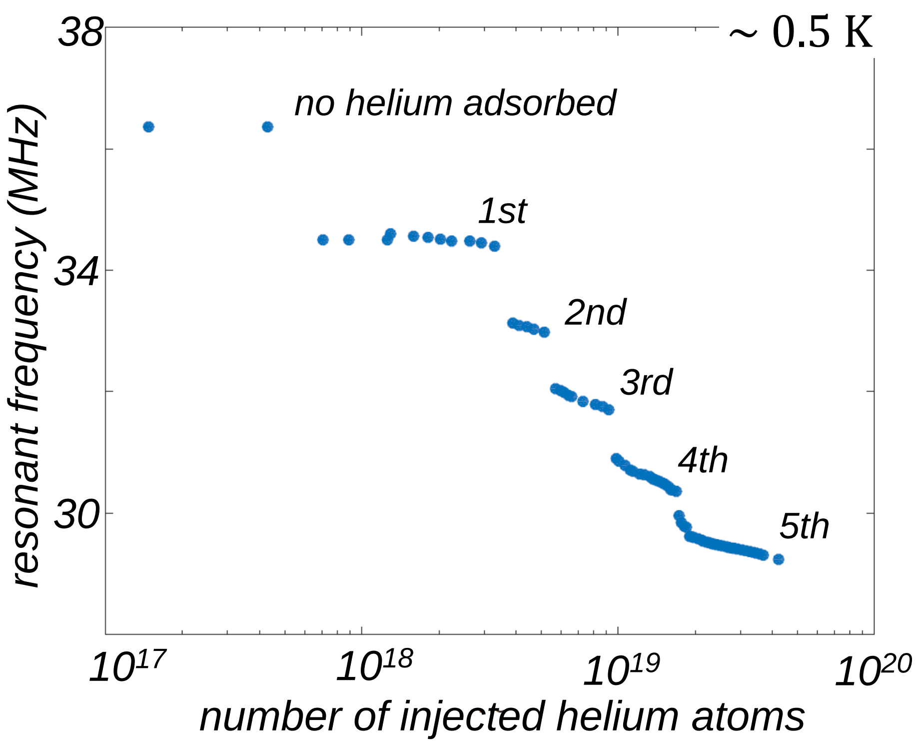
nanotubes with unprecendeted transport quality

Fabry-Pérot Interference



Yang, Urgell, De Bonis, Margańska, Grifoni, Bachtold, PRL 2020

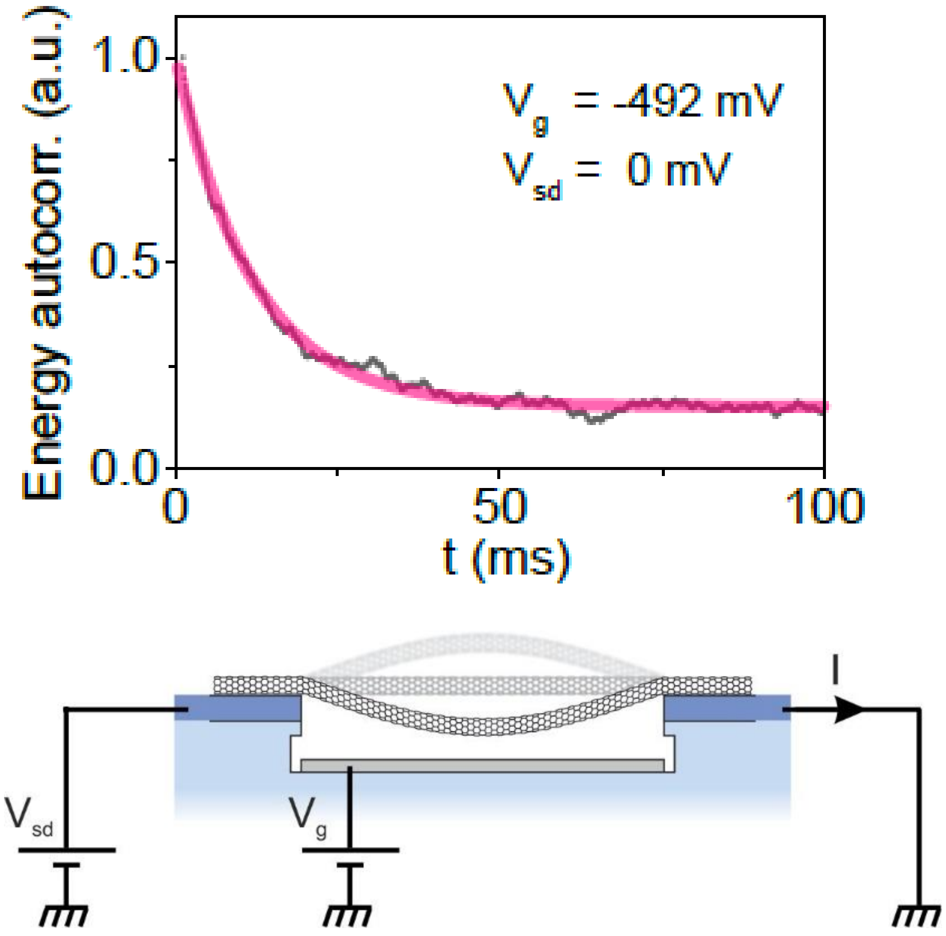
helium superfluid – monolayer by monolayer



		Areal density (atoms/nm^2)	
	f_0 (MHz)	nanotube	graphite
Pristine substrate	36.34	0	0
First layer completed	34.41	11.0	11.4
Second layer completed	32.97	8.1	8.6
Third layer completed	31.69	7.2	7.6
Fourth layer completed	30.39	7.3	7.6

Noury, Vergara-Cruz, Morfin, Plaçais, Gordillo, Boronat, Balibar, Bachtold, PRL 2019

Q = 6.8 million @ 70mK



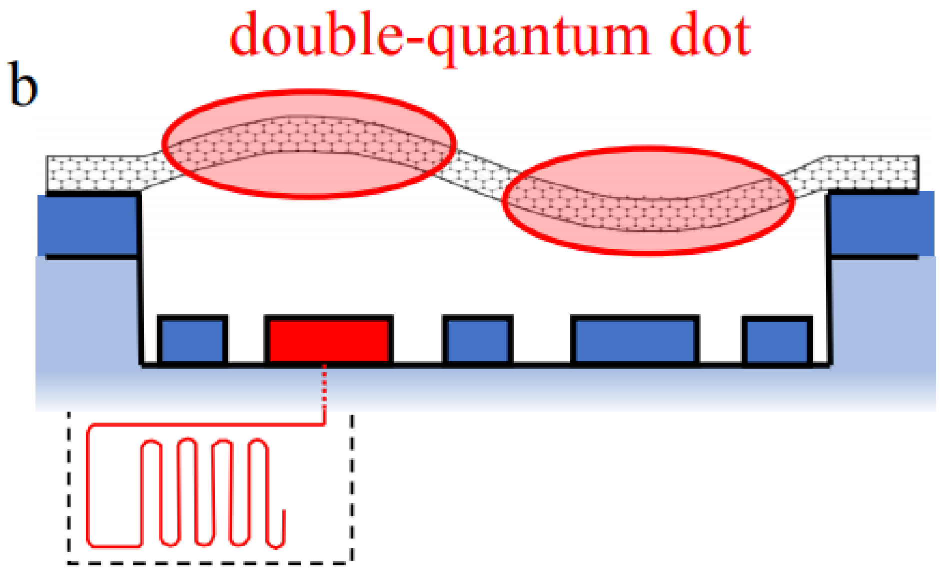
Urgell, Yang, De Bonis, Samanta, Dong, Jin, Bachtold, Nature Phys. 2020

towards a mechanical qubit

qubit measurement	*Andrew Cleland – university Chicago*
Fabrication	*David Czaplewski – national Argonne labs*
theory	*Fabio Pistolesi – CNRS Grenoble*
ICFO	*Chris Møller, Roger Tormo*

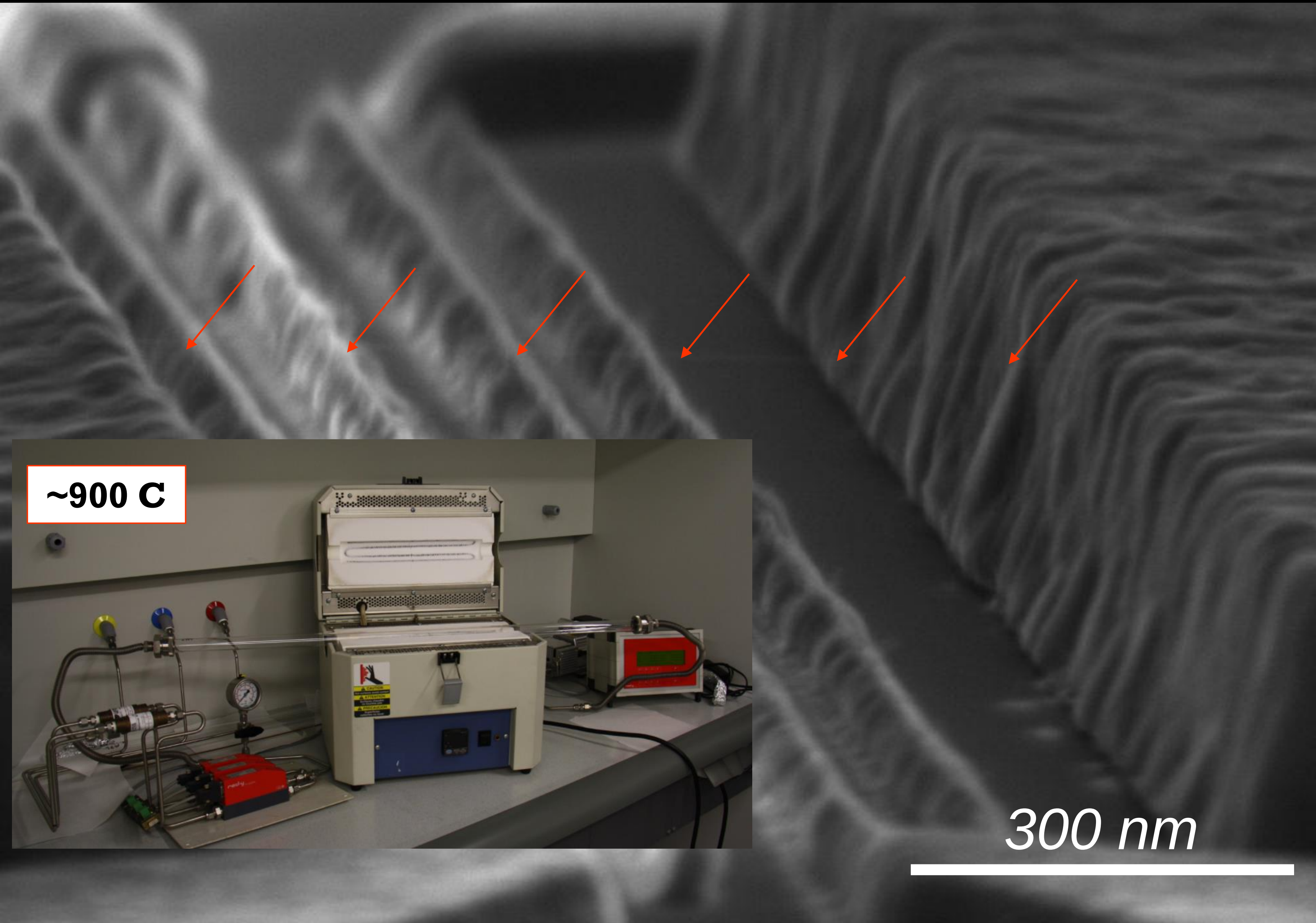
towards a mechanical qubit

Pistolesi, Cleland, Bachtold, arxiv 2020

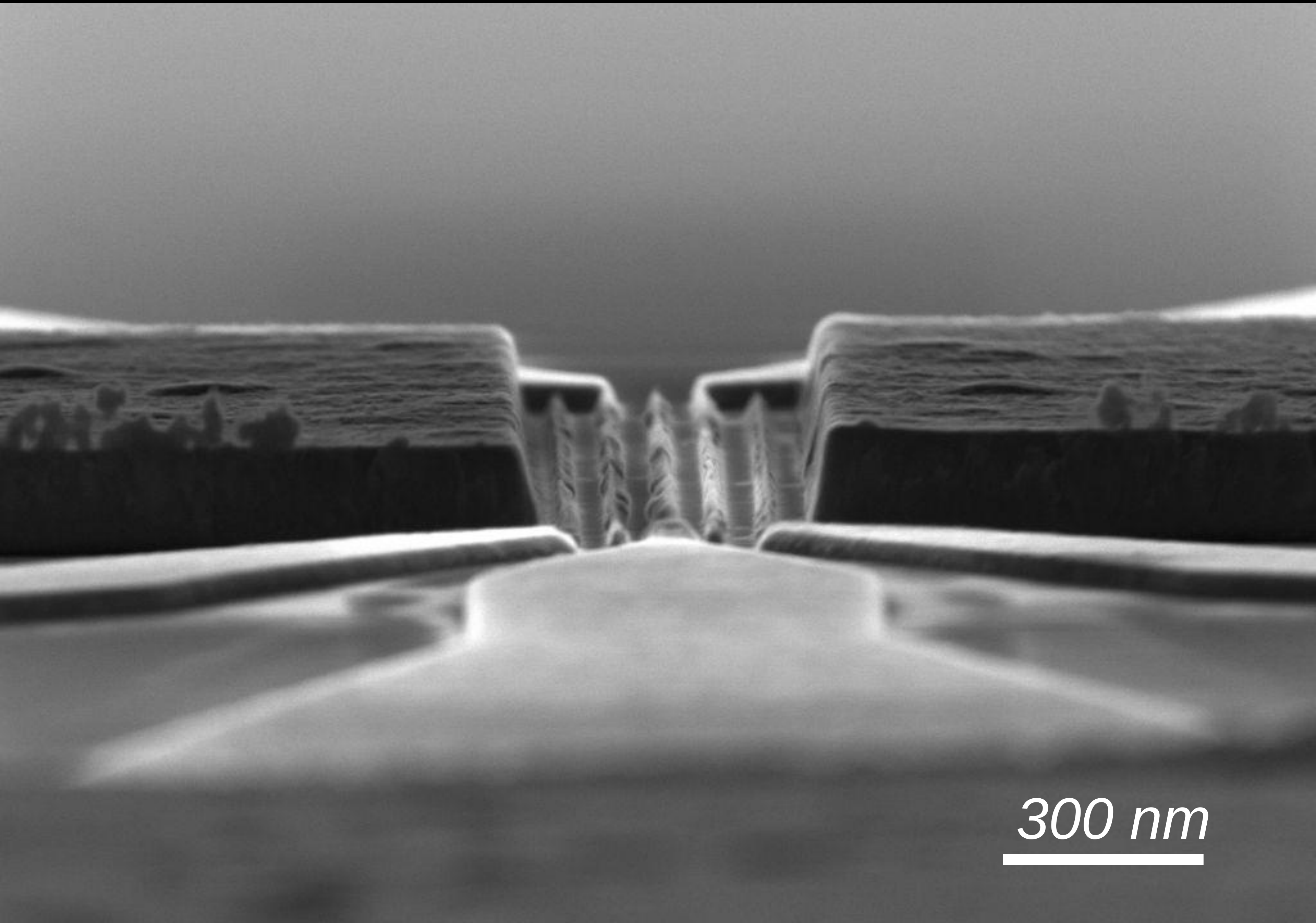


$$H = \hbar\omega_0 a^+ a + t\sigma_z + \hbar g_0 (a^+ + a)\sigma_x,$$

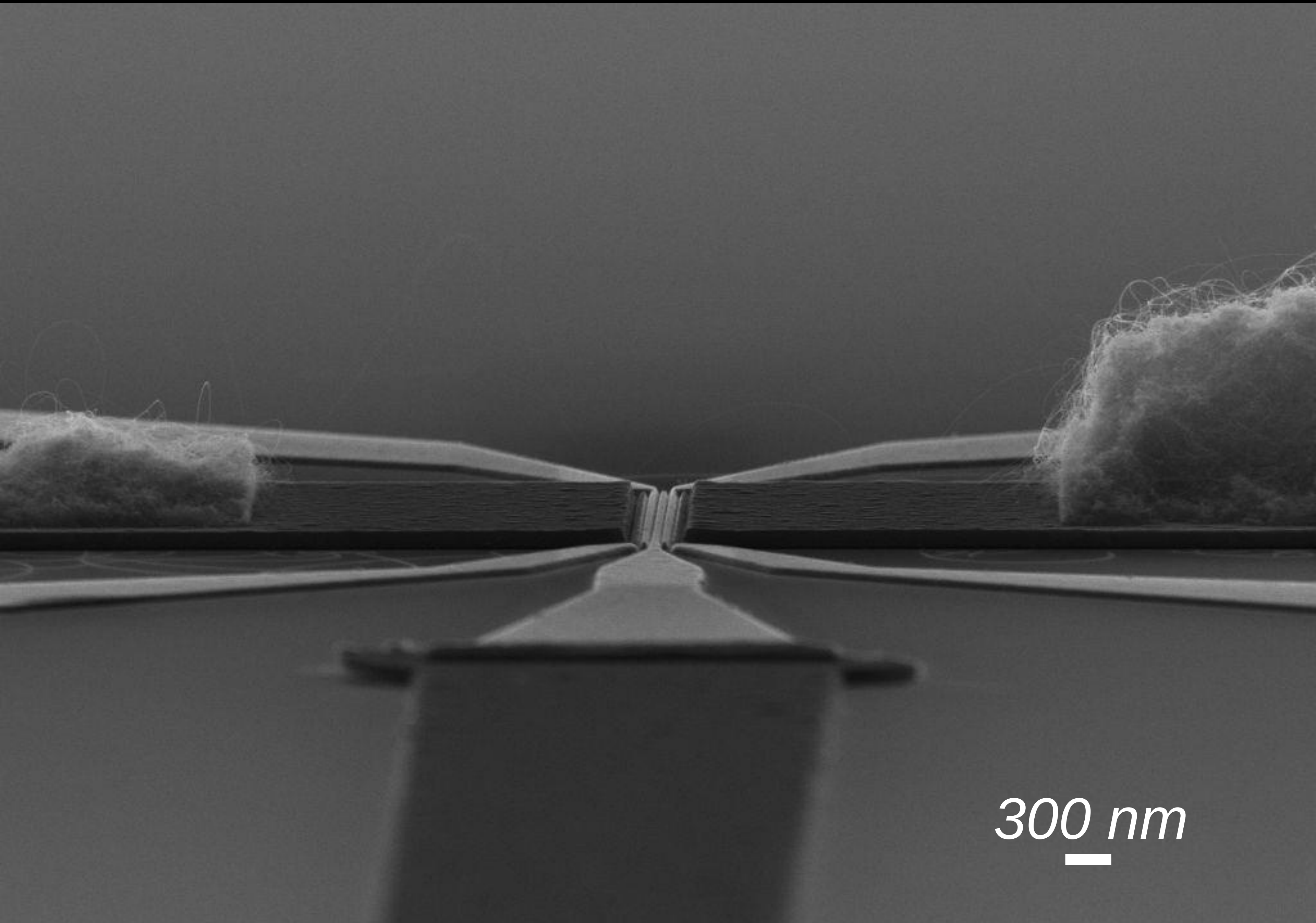
towards a mechanical qubit



towards a mechanical qubit

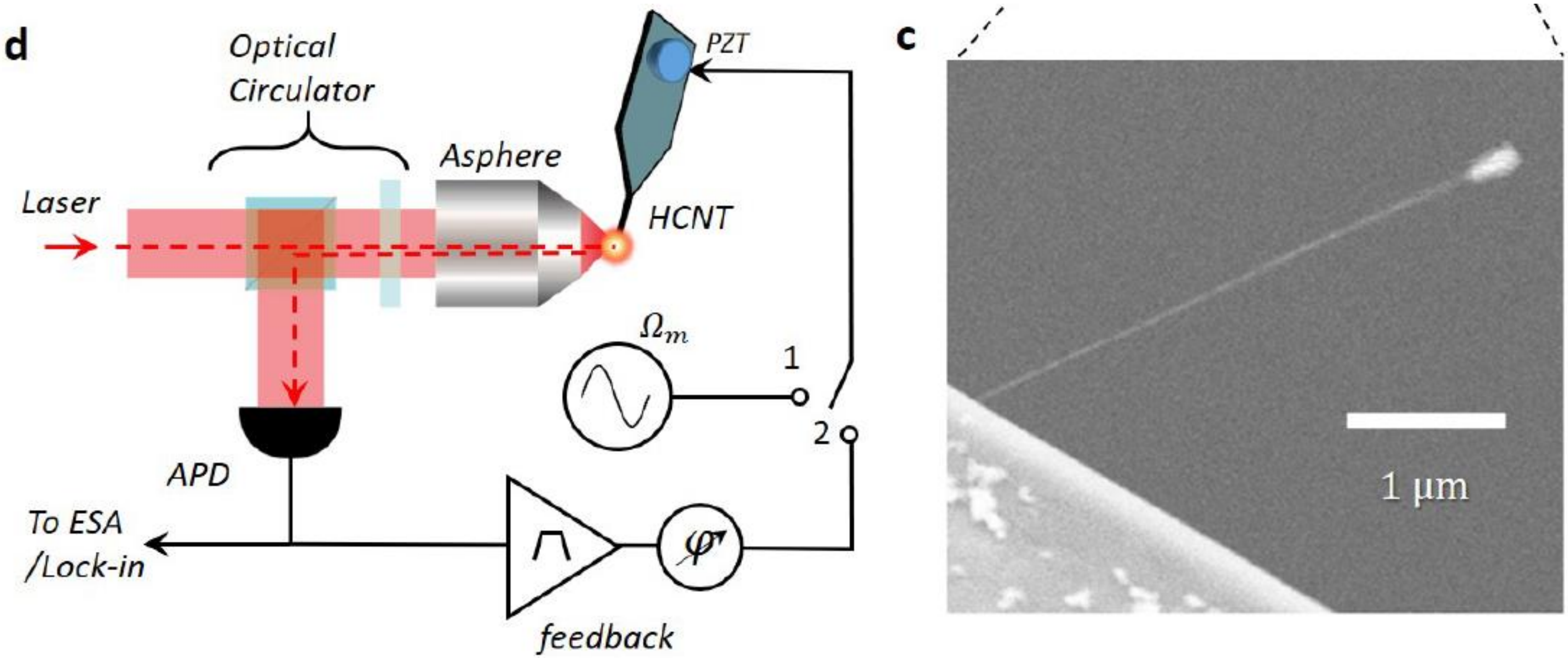


towards a mechanical qubit



Optomechanics with nanotubes

Optical detection of nanotube vibrations

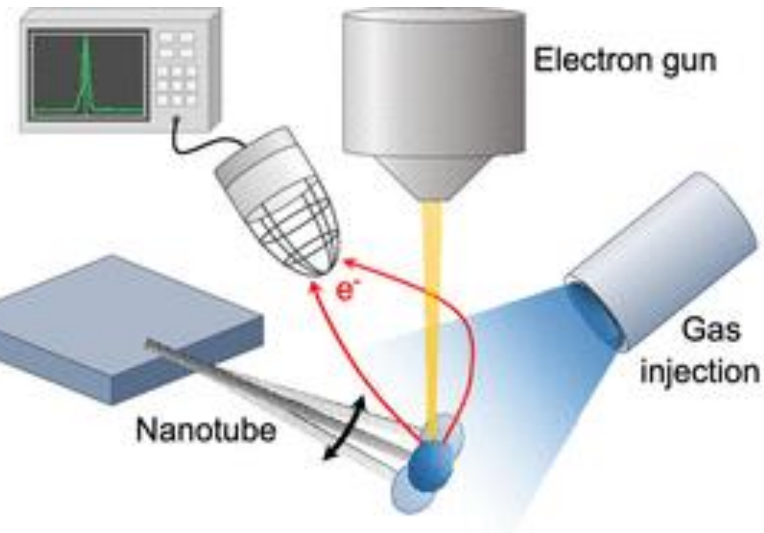


$$S_{FF}^{0.5} = 0.7\,\frac{\mathrm{aN}}{\sqrt{\mathrm{Hz}}}$$ @ 300K

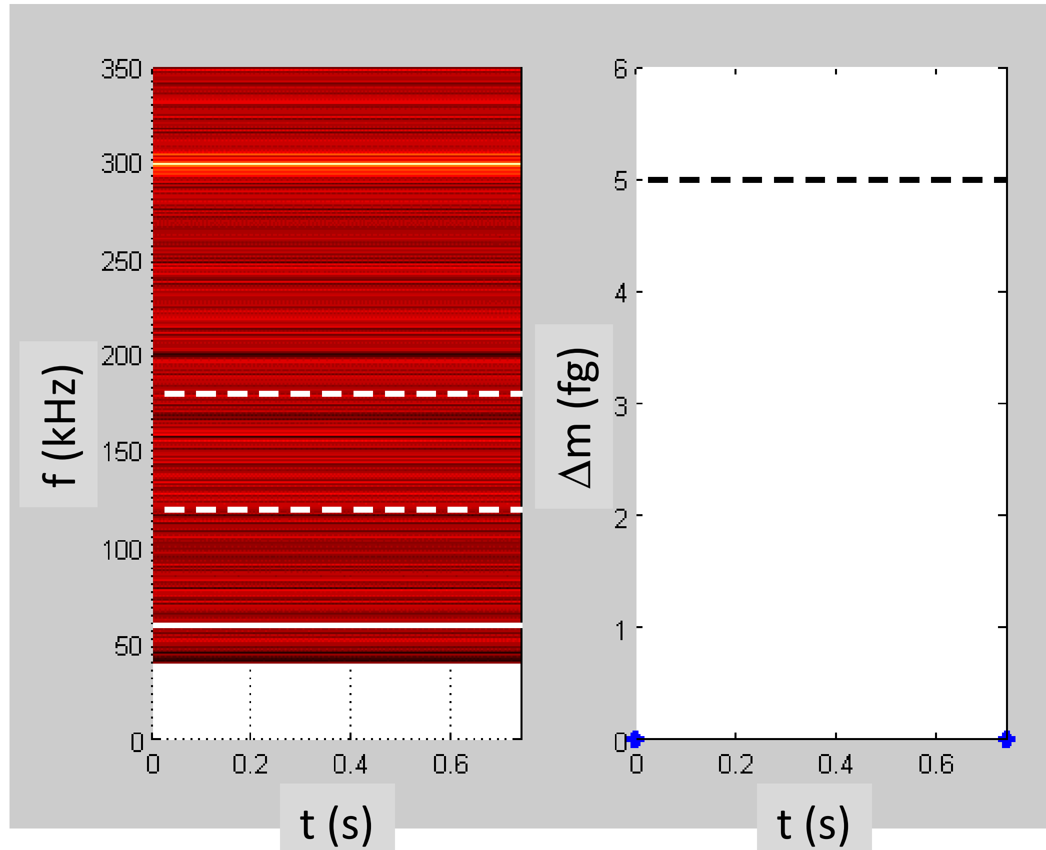
A. Tavernarakis, A. Stavrinadis, A. Nowak, I. Tsioutsios, A. Bachtold, P. Verlot, Nature Com 2018

Controlled growth of one platinum particle with (10-100 nm)^3 size

Gernot Gruber



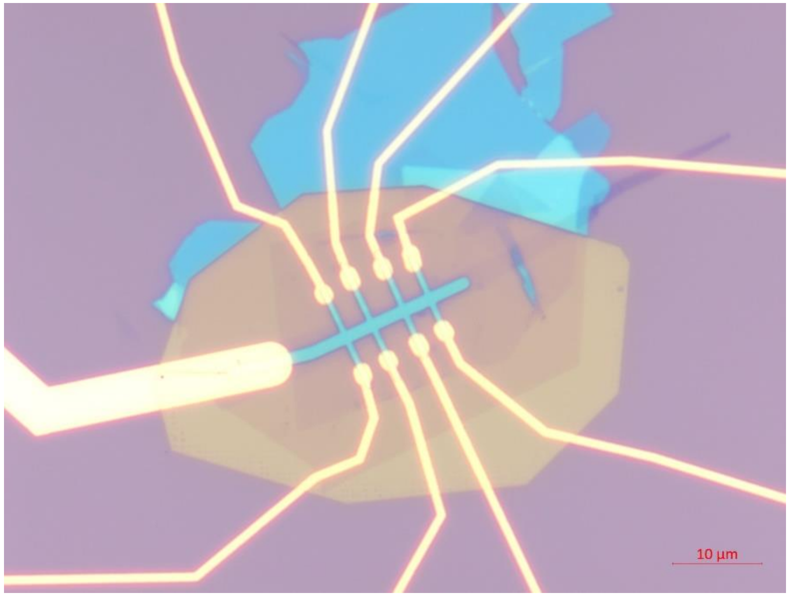
$$\omega_m = \sqrt{k/m}$$



G Gruber, C Urgell, A Tavernarakis, A Stavrinadis, S Tepsic, C Magén, S Sangiao, JM De Teresa, P Verlot, A Bachtold, Nano letters (2019)

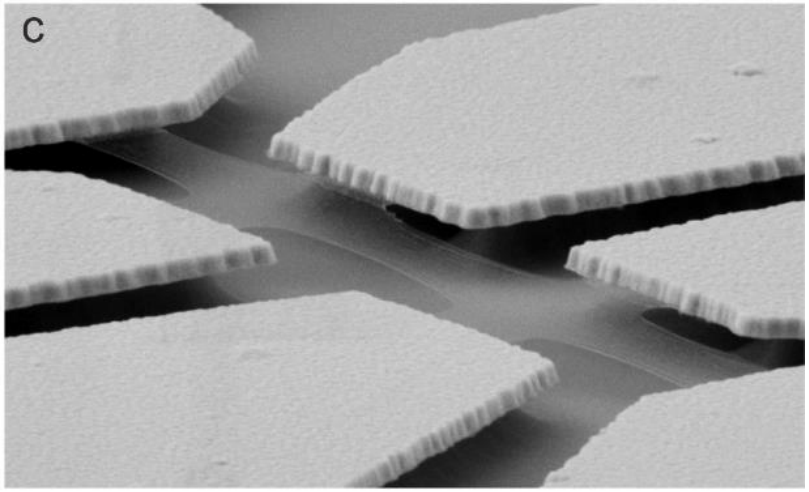
twisted bilayer graphene

Suspending twisted bilayer graphene

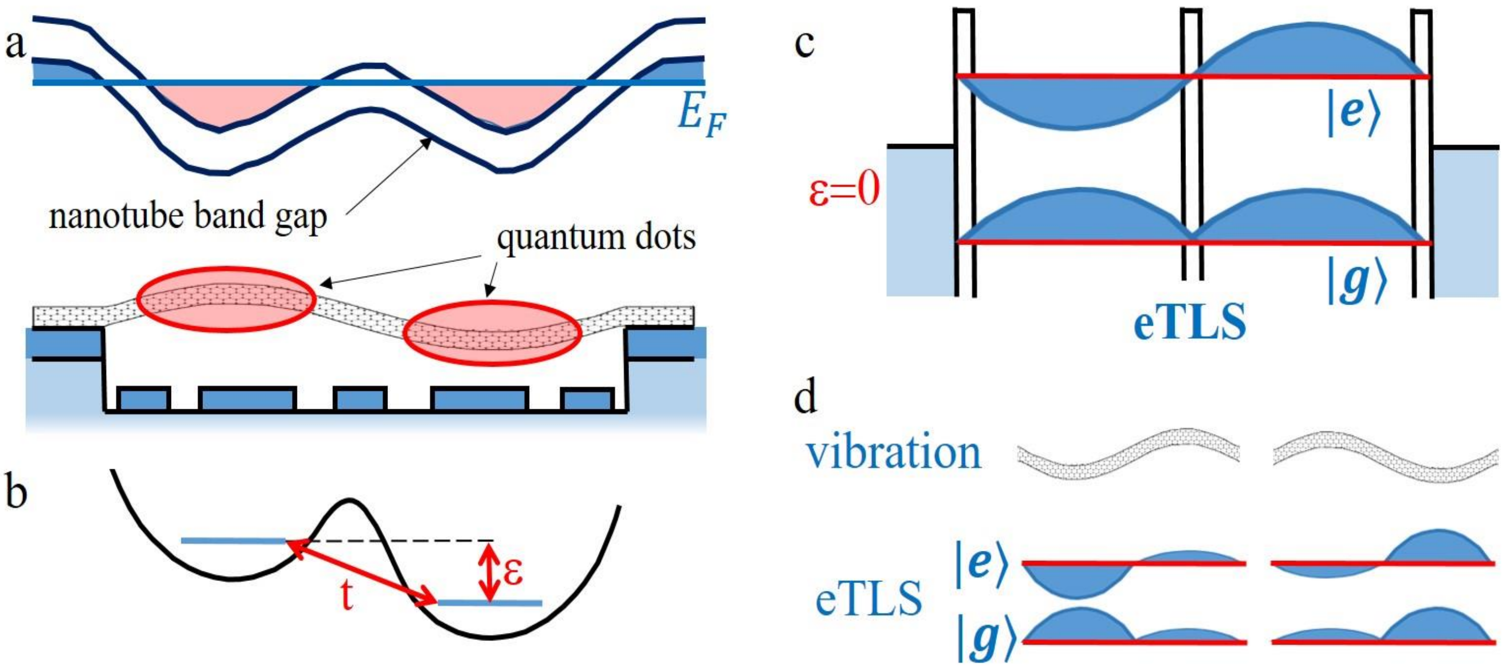


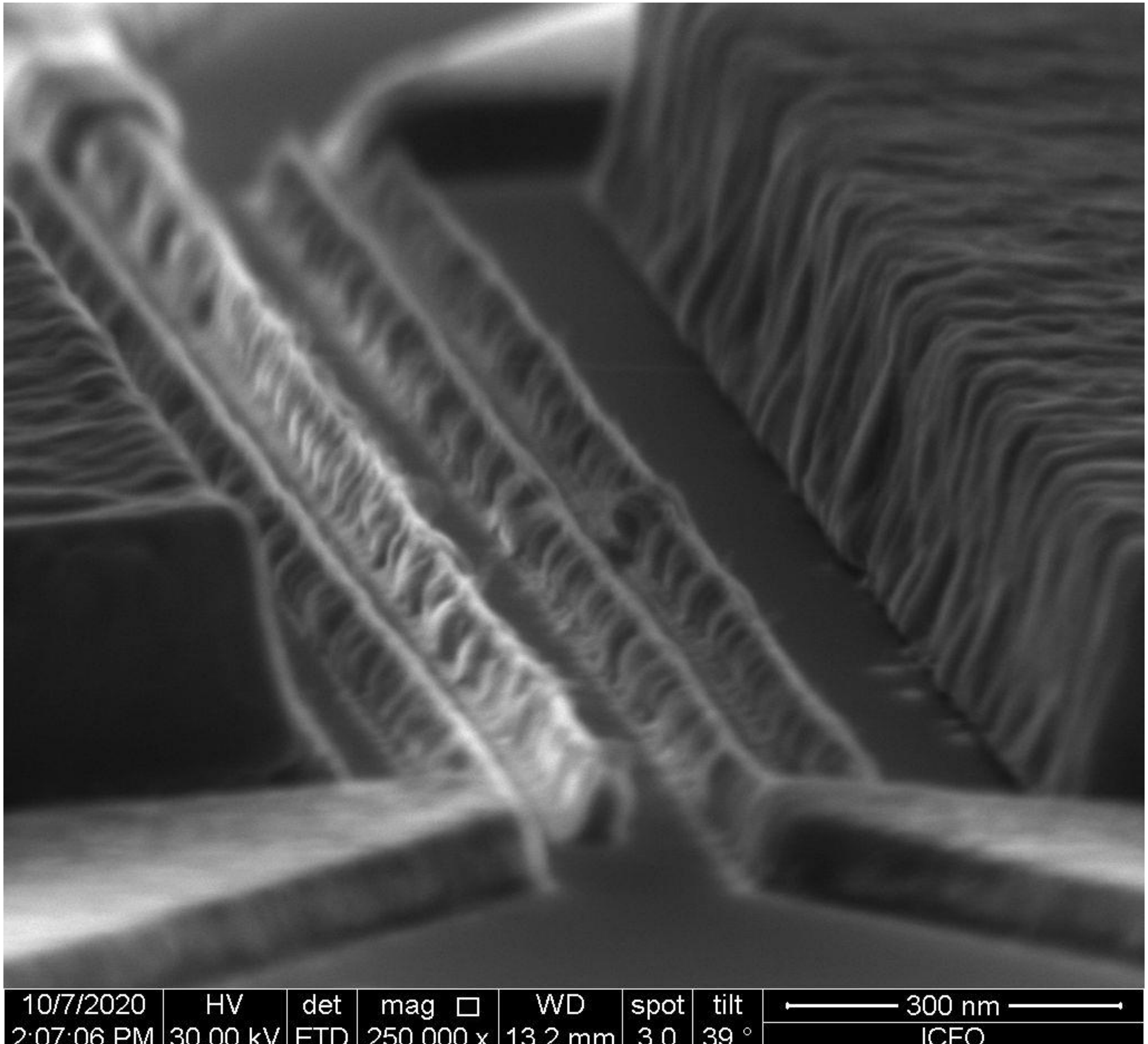
twisted graphene devices following Dima´s fabrication

combining the two fabrication processes



suspended graphene fabricated 12 years ago *thanks*


a
E_F
nanotube band gap
quantum dots
b
t
ε
c
ε=0
|e⟩
|g⟩
eTLS
d
vibration
eTLS
|e⟩
|g⟩


10/7/2020
2:07:06 PM
HV
30.00 kV
det
ETD
mag
250 000 x
WD
13.2 mm
spot
3.0
tilt
39 °
300 nm
ICFO