FNS 2021

FRONTIERS OF NANOMECHANICAL SYSTEMS

Online, 19-21 Jan

BOOK OF ABSTRACTS

FNS 2021 FRONTIERS OF NANOMECHANICAL SYSTEMS * ONLINE, 19-21 JAN

Welcome to FNS 2021

The third international workshop on the Frontiers of Nanomechanical Systems (FNS/2021) will be held online from 19 to 21 January 2021. The talks will be transmitted online from 16:00 to 18:00 (Central European time). With permission from the speakers, the talks will be recorded and upload to the internet so that participants with unfavorable time zones can be updated on the recent progresses in the field. We would like to leave unrestricted access to the talks, so that anyone can listen to them. There will be a virtual poster session. This format for poster sessions has proven highly effective in recent months, facilitating informal discussions between attendees with or without posters.

The workshop series Frontiers of Nanomechanical Systems serve to bring together the international research community engaged in fundamental research on micro- and nano-electromechanical systems (MEMS & NEMS). Nanomechanical systems have emerged as a versatile platform for fundamental science and applications; they are well-controlled, interrogatable, and well-characterized, and fill in the gap between the microscopic world of molecular vibrations and the world of macroscopic vibrational systems. The research frontiers they open lie at the interface between quantum & classical nonlinear dynamics and extend from condensed matter physics to statistical physics, many-body physics far from thermal equilibrium, and nanotechnology.

This will be the third FNS workshop. The first two workshops, which were unanimously considered very successful, were held in the Italian Alps in February 2017 and in Palm Springs in February 2019. They succeeded in bringing together researchers from academia and industry and introduced young researchers to the global scientific community engaged in nanomechanics. The success of these first meetings and the cross-disciplinary nature of the area has led us to work toward holding such meetings biennially. We especially welcome graduate students and postdocs to become active participants in this workshop.

SCIENTIFIC COMMITTEE

Eva Weig (Technical University of Munich)
Fabio Pistolesi (University of Bordeaux)
Hiroshi Yamaguchi (NTT Basic Research Laboratories)
Ho Bun Chan (The Hong Kong University of Science and Technology)
Mark Dykman (Michigan State University)
Michael Roukes (Caltech)

ORGANIZING COMMITTEE

Adrian Bachtold (ICFO, The Institute of Photonic Sciences)

PROGRAM

TIME (CET)	Tuesday 19th January	Wednesday 20th January	Thursday 21th January
16:00 – 16:40	Audrey Bienfait (ENS Lyon)	Javier Tamayo (CSIC Madrid)	Jie Shan (Cornell University)
16:40 – 17:20	Shahal Ilani (Weizmann Institute)	Oded Zilberberg (ETH Zürich)	Edward Laird (Lancaster University)
17:20 – 18:00	Michael Roukes (Caltech)	Flash Talks Poster Session	Poster Session

POSTER SESSION LAYOUT (The Gather Town)

Join in: http://s.ic.fo/FNS2021_PosterSession

FNS 2021 FRONTIERS OF NANOMECHANICAL SYSTEMS * ONLINE, 19-21 JAN

LIST OF POSTERS

POSTER 1…………. A near-field cavity optoelectromechanical charge sensor
POSTER 2…………. Frequency stabilization and noise-induced spectral narrowing in resonators with zero dispersion
POSTER 3…………. Permanent directional heat currents in lattices of optomechanical resonators
POSTER 4…………. Entropy production with quadratic measurement-feedback squeezing in a micromechanical resonator
POSTER 5…………. Strain-mediated interaction between a micromechanical resonator and rare-earth ions
POSTER 6…………. Optomechanical quantum teleportation
POSTER 7…………. Gigahertz phononic integrated circuits on thin-film lithium niobate on sapphire
POSTER 8…………. Frequency stabilization of self-sustained oscillations in sideband-driven electromechanical resonators
POSTER 9…………. Cavity-enhanced spin-wave resonance with a surface acoustic-wave resonator
POSTER 10……..…. Proposal for a Nano Mechanical Qubit
POSTER 11……….... Universal length dependence of tensile stress in nanomechanical string resonators
POSTER 12……..…. Electromechanical control of topological solitons in a chain of parametric-resonator arrays
POSTER 13……..…. A Universal Route to Chaos in Duffing MEMS Resonators
POSTER 14……..…. Topological phonon transport in an optomechanical system
POSTER 15……..…. Two-level system as topological actuator for nanomechanical modes
POSTER 16……..…. Injection locking in an optomechanical coherent phonon source
POSTER 17……..…. Ultrastrong coupling in a carbon nanotube electromechanical device
POSTER 18……..…. Persistent photoinduced change of low-temperature dissipation in AlGaAs/GaAs-based nanomechanical resonators
POSTER 19……..…. Modelling and observation of nonlinear damping in dissipation-diluted nanomechanical resonators
POSTER 20……..…. Imaging a Virus: Advances in 3D Magnetic Resonance Force Microscopy
POSTER 21……..…. Towards a Carbon Nanotube Mechanical Qubit
POSTER 22……..…. Electrical Integration of Silicon Nitride Drum Resonators
POSTER 23…………..Fiber-based angular filtering for high-resolution Brillouin spectroscopy in the 20-300 GHz frequency range
POSTER 24……..…. Coherent optical generation of acoustic phonons in fiber-integrated opto-phononic micropillars
POSTER 25……..…. Atomic Layer deposited nano-mechanical resonators for Silicon photonics
POSTER 26……..…. Mesoporous Thin-Films for Opto-Phononic Devices in the Gigahertz Range
POSTER 27……..…. Ion-Polished Embedded Nanomagnets for Magnetic Resonance Force Microscopy
POSTER 28……..…. Cooling and Self-Oscillation in a Nanotube Electro-Mechanical Resonator
POSTER 29……..…. Membrane-Based Scanning Force Microscopy
POSTER 30……..…. Eigenvalue Braiding around the Trefoil Knot of Degeneracies Near a Triple Exceptional Point
POSTER 31………… Interrelation of elasticity and thermal bath in nanotube cantilevers
POSTER 32………… Phonon localization in 1D quasiperiodic systems

FNS 2021	POSTER 1
TITLE	**A near-field cavity optoelectromechanical charge sensor**
AUTHOR(S) & AFFILIATION(S)	Authors: Hajime Okamoto1,2, Ryan Schilling1, Hendrik Schütz1, Vivishek Sudhir1, Dalziel J. Wilson1, Hiroshi Yamaguchi2, and Tobias J. Kippenberg1 1) Institute of Condensed Matter Physics, École Polytechnique Fédérale de Lausanne (EPFL), 2) NTT Basic Research Laboratories, NTT Corporation
ABSTRACT	We demonstrate a one-chip cavity optoelectromechanical transducer, in which a whispering-gallery optical mode of a SiO2 microdisk cavity evanescently couples to a Si3N4 micromechanical resonator [1] while the mechanical resonator dielectrically couples to Pt electrodes [2]. This transducer enables high-sensitivity displacement detection as well as optical control of mechanical motion via the vacuum optomechanical coupling rate of ~2□ × 50 kHz. It also enables high-efficient electro-optical transduction with the on-resonance half-wave voltage of 6.4 × 10-5 V and the off-resonance half-wave voltage of 4.8 V. The ultra-high charge sensitivity of 6.0 ×10-4 e/Hz0.5 is moreover achieved at room temperature. [1] R. Schilling et al., Phys. Rev. Appl. 5, 054019 (2016). [2] H. Okamoto et al., Appl. Phys. Lett. 108, 153105 (2016).

FNS 2021	POSTER 2
TITLE	**Frequency stabilization and noise-induced spectral narrowing in resonators with zero dispersion**
AUTHOR(S) & AFFILIATION(S)	L. Huang1, S. Soskin2,3, I. A. Khovanov4, R. Mannella5, K. Ninios6, and H. B. Chan1* 1 The Hong Kong University of Science and Technology, 2 National Academy of Sciences of Ukraine, 3 Lancaster University, 4 University of Warwick, 5 Universita di Pisa, 6 University of Florida
ABSTRACT	We design a microelectromechanical resonator with non-monotonic dependence of the eigenfrequency ω on energy E. At the extremum energy E_zd, the dispersion of $\omega(E)$ is zero so that dω/dE=0. In the vicinity of E_zd, the resonance properties are almost as strong as in simple harmonic oscillator. We demonstrate that in the zero-dispersion regime, the spectral peak undergoes substantial narrowing as the noise intensity is increased. The measured spectra are in good agreement with theory. The optimal frequency stability of self-sustained oscillations shows a considerable improvement as compared to conventional nonlinear resonator.

FNS 2021	POSTER 3
TITLE	**Permanent directional heat currents in lattices of optomechanical resonators**
AUTHOR(S) & AFFILIATION(S)	Zakari Denis (presenting the poster) - Laboratoire MPQ, université de Paris, CNRS, 75013 Paris, France Alberto Biella - JEIP, USR 3573 CNRS, Collège de France, PSL Research University, 75321 Paris Cedex 05, France Ivan Favero - Laboratoire MPQ, université de Paris, CNRS, 75013 Paris, France Cristiano Ciuti - Laboratoire MPQ, université de Paris, CNRS, 75013 Paris, France
ABSTRACT	We study the phonon dynamics in lattices of optomechanical resonators where the coupled photonic modes are coherently driven and the mechanical resonators are uncoupled and connected to independent thermal baths. In such systems, quantum photonic fluctuations can mediate phonon transport between distant mechanical resonators. In particular, phase gradients in the illuminating drive can stabilize stationary states exhibiting directional heat currents over arbitrary distance, despite the absence of thermal gradient and of direct coupling between the mechanical resonators. Reference: Z. Denis, A. Biella, I. Favero, and C. Ciuti, Phys. Rev. Lett. 124, 083601

FNS 2021	POSTER 4
TITLE	**Entropy production with quadratic measurement-feedback squeezing in a micromechanical resonator**
AUTHOR(S) & AFFILIATION(S)	Authors: Motoki Asano^1, Takuma Aihara^2, Tai Tsuchizawa^2, and Hiroshi Yamaguchi^1 Affiliations: 1 NTT Basic Research Laboratories, 2 NTT Device Technology Laboratories
ABSTRACT	In this work, we demonstrate a quadratic measurement-feedback protocol in a micromechanical resonator by switching the parametric driving with respect to the measurement outcome in a quadratic measurement with nonlinear optomechanical transduction. This measurement-feedback protocol enables us to induce an additional entropy production which effectively cools the resonator, and allows us to overcome the -3-dB squeezing limit in its non-equilibrium steady state. This nonlinear measurement-feedback control of micromechanical resonators would open the way to investigate non-trivial entropy production and its functional control over linear regimes in the frameworks of stochastic thermodynamics.

FNS 2021	POSTER 5
TITLE	**Strain-mediated interaction between a micromechanical resonator and rare-earth ions**
AUTHOR(S) & AFFILIATION(S)	Ryuichi Ohta, Loïc Herpin, Victor M. Bastidas, Takehiko Tawara, Hiroshi Yamaguchi, and Hajime Okamoto NTT Basic Research Laboratories, NTT Corporation 3-1 Morinosato Wakamiya, Atsugi-shi, Kanagawa 243-0198, Japan
ABSTRACT	We demonstrate the strain-mediated energy modulations of erbium ions embedded in an yttrium silicate mechanical resonator, which originate from their dispersive opto-mechanical coupling $g_0=2\pi\times$ 21.7 Hz. The extremely long-lived excited states of the ions enable a “reversed dissipation regime” in the optical frequency region, where the dissipation rate of the optical resonance is lower than that of the mechanical one. Numerical analyses indicate that g_0 will be improved to exceed both dissipation rates of optical and mechanical resonances using the same fabrication method. Thus, a single-photon strong coupling will be achieved in this opto-mechanical system.

FNS 2021	POSTER 6
TITLE	**Optomechanical quantum teleportation**
AUTHOR(S) & AFFILIATION(S)	Samuel Pautrel, Zakari Denis, Jérémy Bon, Adrien Borne, and Ivan Favero Université de Paris - Laboratoire Matériaux et Phénomènes Quantiques
ABSTRACT	We propose an experimental protocol to realize discrete variable quantum teleportation using optomechanical devices. The photonic polarization superposition state of a single photon is teleported to a phononic superposition of two micromechanical oscillators by means of photon/phonon entanglement generation and optical Bell state measurement using two-photon interference. Verification of the protocol is performed by coherent state transfer between the mechanical devices and light. Simulations show the feasibility of the proposed scheme at millikelvin temperatures using state-of-the-art gigahertz optomechanical devices.

FNS 2021	POSTER 7
TITLE	**Gigahertz phononic integrated circuits on thin-film lithium niobate on sapphire**
AUTHOR(S) & AFFILIATION(S)	Authors: Wentao Jiang*, Felix M. Mayor*, Christopher J. Sarabalis, Timothy P. McKenna, Jeremy D. Witmer, Amir H. Safavi-Naeini (*co-first authors) Affiliation: Department of Applied Physics and Ginzton Laboratory, Stanford University.
ABSTRACT	Acoustic devices play an important role in classical information processing for delaying, filtering, and storing of electric signals. Inspired by integrated photonics, we utilize the phononic analogue of index-guiding in a 1 um wide waveguide on a thin film of lithium niobate on sapphire (LiSa). The strong piezoelectric effect of LiNbO3 allows us to demonstrate a compact and efficient transducer. Combined with the phononic waveguide, we realize acoustic delay lines, racetrack resonators and meander line waveguides. Losses in the racetrack resonators are further characterized at 4 K for potential quantum applications. Finally, we demonstrate efficient three- and four-wave mixing in the phononic waveguide.

FNS 2021	POSTER 8
TITLE	**Frequency stabilization of self-sustained oscillations in sideband-driven electromechanical resonators**
AUTHOR(S) & AFFILIATION(S)	Y. Yan1, B. Zhang1, X. Dong1, M. I. Dykman2 and H. B. Chan1 1. Department of Physics, the Hong Kong University of Science and Technology, Hong Kong, China 2. Department of Physics and Astronomy, Michigan State University, East Lansing, Michigan 48824, USA
ABSTRACT	Two coupled mechanical modes with strongly differing frequencies and decay rates exhibit self-sustained oscillations when pump is applied at the blue-detuned sideband. The phase fluctuations of the modes show near-perfect anti-correlation for fixed pump phase. With a step change of the pump phase, the phase of the two modes settle to new values if noise is absent. After a transient, the phase change of the two modes adds up to the change in pump phase, with the contribution of mode 2 dominating. The findings enable a scheme to stabilize the phase of mode 2 in the presence of noise.

FNS 2021	POSTER 9
TITLE	**Cavity-enhanced spin-wave resonance with a surface acoustic-wave resonator**
AUTHOR(S) & AFFILIATION(S)	D. Hatanaka, Y. Kunihashi, H. Sanada, H. Okamoto and H. Yamaguchi NTT basic Research Laboratories, Atsugi-shi, Kanagawa, 243-0198 JAPAN
ABSTRACT	We investigate magnetoelastic effect induced by acoustically-driven spin-wave resonance in a surface acoustic-wave resonator on a LiNbO3 substrate. Resonant acoustic vibrations with high quality-factor (Q = 4,500) enhance the magnetostrictive interaction to the magnetization precession in a Ni thin film, allowing efficient excitation of spin-wave resonance and significant modulation in the acoustic resonant properties such as resonant frequency and Q-factor. The results indicate the availability of a cavity structure to observe spin-mechanical phenomena and also show the possibility for controlling spin-wave and magnon in a mechanical system.

FNS 2021	POSTER 10
TITLE	**Proposal for a Nano Mechanical Qubit**
AUTHOR(S) & AFFILIATION(S)	F. Pistolesi1, A.N. Cleland2, and A. Bachtold3 1Univ. Bordeaux, CNRS, LOMA, UMR 5798, F-33400 Talence, France 2 2Pritzker School of Molecular Engineering, University of Chicago, Chicago IL 60637, USA 3ICFO - Institut de Ciencies Fotoniques, The Barcelona Institute of Science and Technology, 08860 Castelldefels, Barcelona, Spain
ABSTRACT	Mechanical oscillators have been demonstrated with very high quality factors over a wide range of frequencies. These also couple to a wide variety of fields and forces, making them ideal as sensors. The realization of a mechanically-based quantum bit could therefore provide an important new platform for quantum computation and sensing. Here we show that by coupling one of the flexural modes of a suspended carbon nanotube to the charge states of a double quantum dot defined in the nanotube, it is possible to induce sufficient anharmonicity in the mechanical oscillator so that the coupled system can be used as a mechanical quantum bit. This can however only be achieved when the device enters the ultrastrong coupling regime. We discuss the conditions for the anharmonicity to appear, and we show that the Hamiltonian can be mapped onto an anharmonic oscillator, allowing us to work out the energy level structure and how decoherence from the quantum dot and the mechanical oscillator are inherited by the qubit. Remarkably, the dephasing due to the quantum dot is expected to be reduced by several orders of magnitude in the coupled system. We also outline qubit control, readout protocols and how the qubit can be used as a static force quantum sensor.

FNS 2021	POSTER 11
TITLE	**Universal length dependence of tensile stress in nanomechanical string resonators**
AUTHOR(S) & AFFILIATION(S)	Yannick Klaß University of Konstanz
ABSTRACT	We investigate the tensile stress in freely suspended nanomechanical string resonators, and observe a material-independent dependence on the resonator length. We compare strongly stressed sting resonators fabricated from four different material systems based on amorphous silicon nitride, crystalline silicon carbide as well as crystalline indium gallium phosphide. The tensile stress is found to increase by approximately 50% for shorter resonators. We establish a simple elastic model to describe the observed length dependence of the tensile stress. The model accurately describes our experimental data. This opens a perspective for stress-engineering the mechanical quality factor of nanomechanical string resonators.

FNS 2021	POSTER 12
TITLE	**Electromechanical control of topological solitons in a chain of parametric-resonator arrays**
AUTHOR(S) & AFFILIATION(S)	Hiroshi Yamaguchi and Samer Houri NTT Basic Research Laboratories, NTT Corporation, Atsugi-shi, Kanagawa 243-0198, Japan
ABSTRACT	We theoretically investigate the propagation of topological solitons in one-dimensional coupled parametric-resonator arrays. In rotating-frame phase space, the dynamics of a parametric resonator is described using a double-well pseudo-potential, where two oscillation phase states correspond to two local minima. In a chain of parametric-resonator arrays, the boundary between two different phase domains can propagate along the chain while preserving its shape, so that it can be regarded as a topological soliton. We studied the effect of damping, phase state switching, and symmetry lifting on the dynamics, and found that the topological soliton implemented by using electromechanical resonators allows the propagation dynamics to be precisely electromechanically controlled.

FNS 2021	POSTER 13
TITLE	**A Universal Route to Chaos in Duffing MEMS Resonators**
AUTHOR(S) & AFFILIATION(S)	Samer Houri*, Motoki Asano*, Natsue Yoshimura^, Yasuharu Koike^, Ludovico **Minati^, and Hiroshi Yamaguchi*** * NTT Basic Research Laboratories, NTT Corporation, 3-1, Morinosato Wakamiya, Atsugi, Kanagawa, 243-0198, Japan. ^ Institute of Innovative Research, Tokyo Institute of Technology, Yokohama 226-8503, Japan.
ABSTRACT	The use of perturbation techniques to analyze the dynamics of nonlinear MEMS resonators is a marking feature of this field of research. Perturbation methods assume a “slow-flow” envelope on top a sinusoidal carrier. This approach makes it difficult to generate chaos since the latter is not a perturbation phenomena. We generate chaos within the perturbation regime, by increasing the slow flow dimensions

FNS 2021	POSTER 14
TITLE	**Topological phonon transport in an optomechanical system**
AUTHOR(S) & AFFILIATION(S)	Tirth Shah Max Planck Institute for the Science of Light, Erlangen, Germany
ABSTRACT	Recent advances in cavity-optomechanics have now made it possible to use light to measure mechanical motion to the individual phonons. Simultaneously, microfabrication techniques have enabled small-scale on-chip optomechanical circuits. Motivated by these developments, we present the observation of topological phonon transport within a multiscale optomechanical crystal. Using sensitive, spatially resolved optical read-out, we detect thermal phonons in a 0.325−0.34 GHz band traveling along a topological edge channel, with substantial reduction in backscattering. This work further advances the ongoing effort to miniaturize topological phononic devices down to the nanoscale, opening the way to GHz frequency acoustic wave circuits.

FNS 2021	POSTER 15
TITLE	**Two-level system as topological actuator for nanomechanical modes**
AUTHOR(S) & AFFILIATION(S)	C. Dutreix, Université de Bordeaux, France and CNRS, LOMA, UMR 5798, Talence, F-33400, France R. Avriller, Université de Bordeaux, France and CNRS, LOMA, UMR 5798, Talence, F-33400, France B. Lounis, Institut d'Optique & CNRS, LP2N UMR 5298, F-33400 Talence, France, AND Université de Bordeaux, LP2N, F-33400 Talence, France F. Pistolesi, Université de Bordeaux, France and CNRS, LOMA, UMR 5798, Talence, F-33400, France
ABSTRACT	This work shows how a nanomechanical oscillator coupled to an open quantum two-level system can exhibit exceptional degeneracy points in its spectrum. One can then exploit this degeneracy to manipulate the vectorial polarization of the mechanical oscillations in real space. This enables a topological and chiral actuation between the modes, even in the presence of strong quantum fluctuations due to the spontaneous emission of the two-level system

FNS 2021	POSTER 16
TITLE	**Injection locking in an optomechanical coherent phonon source**
AUTHOR(S) & AFFILIATION(S)	G. Arregui,1, 2 M. F. Colombano,1,3 J. Maire,1 A. Pitanti,4 N. E. Capuj,5, 6 A. Griol,7 A. Martínez,7 C. M. Sotomayor-Torres,1, 8 and D. Navarro-Urrios3 1Catalan Institute of Nanoscience and Nanotechnology (ICN2), CSIC and The Barcelona Institute of Science and Technology, Campus UAB, Bellaterra, 08193 Barcelona, Spain 2Dept. de Física, Universitat Autónoma de Barcelona, 08193 Bellaterra, Spain 3MIND-IN2UB, Departament d'Enginyeria Electrónica i Biomédica, Facultat de Física, Universitat de Barcelona, Martí Franqués 1, 08028 Barcelona, Spain 4NEST Lab., CNR - Istituto di Nanoscienze and Scuola Normale Superiore, Piazza San Silvestro 12, 56217 Pisa, Italy 5Depto. Física, Universidad de La Laguna, 38200 San Cristóbal de La Laguna, Spain 6Instituto Universitario de Materiales y Nanotecnología, Universidad de La Laguna, 38071 Santa Cruz de Tenerife, Spain 7Nanophotonics Technology Center, Universitat Politécnica de Valencia, 46022 Valencia, Spain 8ICREA - Instituciò Catalana de Recerca i Estudis Avançats, 08010 Barcelona, Spain
ABSTRACT	Spontaneous locking of the phase of a optomechanical oscillator (OMO) to an external radiofrequency tone is demonstrated in a sideband-unresolved system. We employ a pump-probe phonon detection scheme based on an independent optomechanical cavity to isolate the mechanical dynamics. The lock range of the oscillation frequency, i.e., the Arnold tongue, is determined over a range of external reference strengths, evidencing the possibility to tune the OMO frequency over tens of kHz. The stability of the locked OMO is evaluated via its phase noise, showing a maximum suppression of 44 dBc/Hz at 1 kHz offset for a 100 MHz mechanical oscillator.

FNS 2021	POSTER 17
TITLE	**Ultrastrong coupling in a carbon nanotube electromechanical device**
AUTHOR(S) & AFFILIATION(S)	Florian Vigneau - Department of Materials, University of Oxford, Oxford OX1 3PH, United Kingdom Juliette Monsel - Department of Microtechnology and Nanoscience (MC2), Chalmers University of Technology, S-412 96 Göteborg, Sweden Jorge Tabanera - Department of Structure of Matter, Thermal Physics and Electrodynamics, Universidad Complutense de Madrid, Pl. de las Ciencias 1. 28040 Madrid, Spain Léa Bresque - Univ. Grenoble Alpes, CNRS, Grenoble INP, Institut Néel, 38000 Grenoble, France FedericoFedele - Department of Materials, University of Oxford, Oxford OX1 3PH, United Kingdom Alexia Auffèves - Univ. Grenoble Alpes, CNRS, Grenoble INP, Institut Néel, 38000 Grenoble, France Janet Anders - Physics and Astronomy, University of Exeter, Exeter EX4 4QL, United Kingdom Institut für Physik, Potsdam University, 14476 Potsdam, Germany Juan Parrondo - Department of Structure of Matter, Thermal Physics and Electrodynamics, Universidad Complutense de Madrid, Pl. de las Ciencias 1. 28040 Madrid, Spain Natalia Ares - Department of Materials, University of Oxford, Oxford OX1 3PH, United Kingdom
ABSTRACT	The ultrastrong coupling of single-electron tunnelling and nanomechanical motion opens exciting opportunities to explore fundamental questions and develop new quantum technologies. We have measured and modelled this electromechanical coupling in a fully-suspended carbon nanotube device and reached the conclusion that the gm/ωm ratio, where gm is the coupling strength and ωm is the mechanical frequency, is the highest among current electromechanical platforms. We obtain gm/ωm =1.35 with gm/2π = 440 ± 20 MHz and ωm/2π = 324 MHz, well within the ultrastrong coupling regime. Even higher ratios could be achieved with improvement on device design.

FNS 2021	POSTER 18
TITLE	**Persistent photoinduced change of low-temperature dissipation in AlGaAs/GaAs-based nanomechanical resonators**
AUTHOR(S) & AFFILIATION(S)	Authors: Andrey A. Shevyrin 1, Arthur G. Pogosov 1,2, Askhat K. Bakarov 1,2, Alexander A. Shklyaev 1,2 Affiliations: 1 Rzhanov Institute of Semiconductor Physics SB RAS, Novosibirsk, Russia 2 Novosibirsk State University, Novosibirsk, Russia
ABSTRACT	Low-temperature dissipation is studied in AlGaAs/GaAs-based nanomechanical resonators with a two-dimensional electron gas. The temperature dependence of dissipation demonstrates a peak near 30 K. A short illumination leads to a persistent change in the quality factor similar to the well-known persistent photoconductivity effect. Moreover, the illumination persistently suppresses the dissipation peak. This suppression shows that the peak at 30 K is not related to the thermoelastic and Akhiezer damping. A hypothesis associating the peak with DX-centers or similar low-symmetry and light-sensitive centers is proposed. The observed effects should be taken into account when studying the low-temperature dissipation using optical methods.

FNS 2021	POSTER 19
TITLE	**Modelling and observation of nonlinear damping in dissipation-diluted nanomechanical resonators**
AUTHOR(S) & AFFILIATION(S)	Authors: Letizia Catalini, Massimiliano Rossi**, Eric C. Langman, Albert Schliesser Affiliation: Niels Bohr Institute, University of Copenhagen, Denmark **Current affiliation: Photonics Laboratory, ETH Zürich, Switzerland
ABSTRACT	Dissipation dilution enables extremely low linear loss in stressed nanomechanical resonator. Here, we report on the observation of nonlinear dissipation in such resonators. We introduce an analytical full 3D model, which can be numerically evaluated using final-element model for arbitrary geometries. We predict nonlinear loss and Duffing shift in soft-clamped membrane resonators. We find good agreement with the model for low-order soft-clamped modes. Our analysis also reveals quantitative connections between these nonlinearities and dissipation dilution. This is of interest for future device design and can provide important insight when diagnosing the performance of dissipation dilution in an experimental setting.

FNS 2021	POSTER 20
TITLE	**Imaging a Virus: Advances in 3D Magnetic Resonance Force Microscopy**
AUTHOR(S) & AFFILIATION(S)	M.-D. Krass, N. Prumbaum, U. Grob, R. Pachlatko, H. Takahashi, A. Eichler, C. L. Degen Spin Physics, Department of Physics, ETH Zurich, Zürich, Switzerland
ABSTRACT	The goal of nanoscale magnetic resonance imaging (NanoMRI) is the 3D visualization of nuclear spin densities inside objects with near-atomic spatial resolution. One promising candidate for NanoMRI is magnetic resonance force microscopy (MRFM) which employs an ultrasensitive nanomechanical transducer to detect the interaction between nuclear spins and a magnetic field gradient. Recently, we achieved an important milestone on the way to establish subnanometerresolution MRFM by demonstrating line scans with a 1D resolution of 0.9 nanometer [1]. We also present first data from our latest 3D scan of single influenza virus particles involving new image reconstruction methods. [1] U. Grob, M. D. Krass, M. Héritier, R. Pachlatko, J. Rhensius, J. Košata, B. A. Moores, H. Takahashi, A. Eichler, and C. L. Degen, Nano Letters (2019), 19, 11, 7935 – 7940

FNS 2021	POSTER 21
TITLE	**Towards a Carbon Nanotube Mechanical Qubit**
AUTHOR(S) & AFFILIATION(S)	Christoffer B. Moller1, Roger Tormo Queralt1, Sergio L. De Bonis1, Chandan Samanta1, David Czaplewski2, Andrew N. Cleland3, Fabio Pistolesi4, Adrian Bachtold1 1ICFO - The Institute of Photonic Sciences, Barcelona, Spain 2Argonne National Lab, Illinois, USA 3University of Chicago, Illinois, USA 4University of Bordeaux, Bordeaux, France
ABSTRACT	We present our efforts towards realizing the first ever mechanical qubit [1]. We employ a pristine [2], suspended carbon nanotube with exceptional cryogenic mechanical coherence [3] and seek to significantly tailor the energy potential of its mechanical vibrations by strongly coupling its motion to a localized double quantum dot. We present measurements which demonstrate operation in the ultra-strong electromechanical coupling regime generated by an electrostatic force between a biased gate electrode and a single charge quantum dot on a suspended carbon nanotube. We further present our efforts to extend these capabilities to a high frequency nanotube, suspended above 5 independently biased gates forming a double quantum dot [4]. The gates grant control of the interaction between the quantum dots, and their coupling to mechanical vibrations enable a tunable mechanical energy potential, essential in the formation of the mechanical qubit. [1] F. Pistolesi, A. N. Cleland, A. Bachtold, arXiv:2008.10524, (2020) [2] W. Yang et al. PRL, 125, 187701 (2020) [3] J. Moser et al., Nat. Nanotech. 9, 1007 (2014) [4] I. Khivrich, A. A. Clerk and S. Ilani, Nat. Nanotech., 14, 161-167 (2019)

FNS 2021	POSTER 22
TITLE	**Electrical integration of silicon nitride drum resonators**
AUTHOR(S) & AFFILIATION(S)	Srisaran Venkatachalama, Ronghua Zhoua, Andrew Feffermanb, Mohammed Zaknounea, Eddy Collinb, and Xin Zhoua,* a) IEMN-CNRS UMR 8520, Univ. Lille, Villeneuve d'Ascq 59650, France, To contact: xin.zhou@iemn.fr b) Univ. Grenoble Alpes, Institut Néel - CNRS UPR2940, 25 rue des Martyrs, BP 166, 38042 Grenoble, France
ABSTRACT	Silicon nitride (SiN) strings and membranes, fabricated on pre-stressed thin film emerged as promising devices. Because they have nanogram effective mass and easily achieve in MHz range resonance frequency with high quality factor. Unfortunately, the insulant feature greatly limits implementations of SiN mechanical resonator in an electrical system. Integration of the double-clamped beam structure has been successfully demonstrated in both capacitive coupling and dielectric coupling schemes [1]. However, the coupling effect is quite weak and its improvement requires a demanding nanofabrication technique. In this work, we introduce our recent progress in developing a new SiN drum resonator with capacitive coupling design, which was achieved with standard CMOS compatible fabrication process. We will also present their basic device properties at room temperature and integrations with a microwave optomechanical platform at 4K temperature.

FNS 2021	POSTER 23
TITLE	**Fiber-based angular filtering for high-resolution Brillouin spectroscopy in the 20-300 GHz frequency range**
AUTHOR(S) & AFFILIATION(S)	A. Rodriguez, Priya, O. Ortiz, P. Senellart, C. Gomez-Carbonell, A. Lemaître, M. Esmann, N.D. Lanzillotti-Kimura
ABSTRACT	We develop a pragmatic, experimental approach for conventional Brillouin spectroscopy that can integrate a widely tunable excitation-source. Our setup combines a fiber-based angular filtering and spectral filtering based on a single etalon and a double grating spectrometer. The angular filtering with a single-mode fiber is permitted by the angular offset between the incoming laser and scattered signal due to the double optical resonance. This configuration allows probing confined acoustic phonon modes in the 20-300 GHz frequency range with excellent laser rejection and high spectral resolution.

FNS 2021	POSTER 24
TITLE	**Coherent optical generation of acoustic phonons in fiber-integrated opto-phononic micropillars**
AUTHOR(S) & AFFILIATION(S)	Omar Ortiz1, Florian Pastier2, Anne Rodriguez1, Priya1, Aristide Lemaître1, Carmen Gomez Carbonell1, Isabelle Sagnes1, Abdelmounaim Harouri1, Pasacale Senellart1, Valerian Giesz2, Martin Esmann1 and Norberto Daniel Lanzillotti-Kimura1 1Université Paris-Saclay, CNRS, Centre de Nanosciences et de Nanotechnologies (C2N), 91120 Palaiseau, France 2Quandela SAS, 10 Boulevard Thomas Gobert, 91120 Palaiseau, France
ABSTRACT	We present a novel approach to measure coherent phonons in optophononic micropillars by gluing an individual 2.8 µm diameter micropillar to the tip of a single-mode fiber. Then, by using a novel fibered pump and probe detection scheme, we have coherently generated and detected phonons at hundreds of gigahertz. The new fiber integrated micropillar with the novel pump-probe technique allow us to identify the presence of coherent phonons in the GHz-THz range with unprecedented robustness and reproducibility.

FNS 2021	POSTER 25
TITLE	**Atomic Layer deposited nano-mechanical resonators for Silicon photonics**
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ABSTRACT	Atomic layer deposition (ALD) is the high-precision conformal growth of a wide range of dielectrics thin films over a broad array of substrates. These ultra-thin (<10nm) ALD membranes possess very desirable mechanical properties such ultra-low mass and stiffness, for applications in nano-mechanical force and mass sensing. We determine the optical gradient force generated by the interaction of an alumina membrane suspended over a silicon waveguide mode using finite element methods (FEM). We have also developed an all dry fabrication method of suspending ALD alumina membranes using an e-beam resist (CSAR-62) as a sacrificial release layer.

FNS 2021	POSTER 26
TITLE	**Mesoporous Thin-Films for Opto-Phononic Devices in the Gigahertz Range**
AUTHOR(S) & AFFILIATION(S)	Edson R. Cardozo de Oliveira1, Nicolas L. Abdala2, Martin Esmann1, Maria C. Fuertes3, Paula C. Angelomé3, Omar Ortiz1, Axel Bruchhausen4, Hernan Pastoriza4, Bernard Perrin5, Galo J. A. A. Soler-Illia2, and Norberto D. Lanzillotti-Kimura1 1 Université Paris-Saclay, CNRS, Centre de Nanosciences et de Nanotechnologies, 91120 Palaiseau, France 2 Instituto de NanoSistemas – Universidad Nacional de San Martín-CONICET, Buenos Aires, Argentina 3 Gerencia Química & Instituto de Nanociencia y Nanotecnología, Centro Atómico Constituyentes, CNEA-CONICET, Buenos Aires, Argentina 4 Centro Atómico Bariloche & Instituto de Nanociencia y Nanotecnología, CNEA-CONICET, Rio Negro, Argentina 5 Sorbonne Université, CNRS, Institut des NanoSciences de Paris, INSP, F-75005 Paris, France
ABSTRACT	Nanoscale mesoporous materials present a high surface-to-volume ratio and tailorable mesopores, which allow the incorporation of chemical functionalization to nanoacoustics. Here, we present multilayered nanoacoustic resonators based on mesoporous SiO_2 and TiO_2 thin-films showing acoustic resonances in the 5-100 GHz range, and compare experimental results with simulations. Finally, we propose new complex mesoporous systems with potential for nanoacoustic sensor applications.

FNS 2021	POSTER 27
TITLE	**Ion-Polished Embedded Nanomagnets for Magnetic Resonance Force Microscopy**
AUTHOR(S) & AFFILIATION(S)	Raphael Pachlatko, Marc-Dominik Krass, Martin Héritier, Dr. Urs Grob, Dr. Alexander Eichler, Prof. Dr. Christian Degen Affiliation: Research group of Prof. Dr. Christian Degen at the Physics department of ETH Zurich (D-PHYS)
ABSTRACT	Magnetic Resonance Force Microscopy (MRFM) combines Nuclear Magnetic Resonance with Atomic Force Microscopy and Microwave Electronics to single spin-active samples. System stability is paramount for MRFM measurements due to long integration times; cantilever pinning and resonance frequency play a significant role in it. By adopting a planar geometry for the magnetic field gradient source inside the microstrip (Embedded Nanomagnets) we aim to eliminate cantilever pinning phenomena and resonance frequency spikes. The fabrication of the Embedded Nanomagnets makes heavy use of both Glancing Angle and Steep Angle Ion Milling.

FNS 2021	POSTER 28
TITLE	**Cooling and Self-Oscillation in a Nanotube Electro-Mechanical Resonator**
AUTHOR(S) & AFFILIATION(S)	C. Urgell (1), W. Yang (1), S. L. de Bonis (1), C. Samanta (1), M. J. Esplandiu (2), Q. Dong (3), Y. Jin (3) and A. Bachtold (1). (1) ICFO - Institut de Ciències Fotòniques, The Barcelona Institute of Science and Technology, Mediterranean Technology Park, 08860 Castelldefels (Barcelona), Spain. (2) Catalan Institute of Nanoscience and Nanotechnology (ICN2), CSIC and BIST, Campus UAB, Bellaterra, 08193 Barcelona, Spain. (3) Centre de Nanosciences et de Nanotechnologies (C2N), CNRS, Univ. Paris-Sud, Univ. Paris-Saclay, 91120 Palaiseau, France.
ABSTRACT	Nanomechanical resonators are used with great success to couple mechanical motion to other degrees of freedom, such as photons, spins, and electrons. Mechanical vibrations can be efficiently cooled and amplified using photons, but not with other degrees of freedom. In this contribution, we demonstrate a simple yet powerful method for cooling, amplification, and self-oscillation using electrons. This is achieved by applying a constant (DC) current of electrons through a suspended nanotube in a dilution fridge. We demonstrate cooling down to 4.6 quanta of vibrations. We also observe self-oscillation, which can lead to prominent instabilities in the electron transport through the nanotube. We attribute the origin of the observed cooling and self-oscillation to an electrothermal effect. This work shows that electrons may become a useful resource for cooling the mechanical vibrations of nanoscale systems into the quantum regime. This work is published in Nature Physics 16, 32-37 (2020).

FNS 2021	POSTER 29
TITLE	**Membrane-Based Scanning Force Microscopy**
AUTHOR(S) & AFFILIATION(S)	D. Hälg, T. Gisler, H. Mattiat, U. Grob, M.-D. Krass, M. Héritier, A.-K. Thamm, R. Schirhagl, A. Eichler, C. Degen - Laboratory of Solid State Physics, ETH Zurich E. Langman, L. Catalini, Y. Tsaturyan, A. Schliesser - Niels Bohr Institute, Copenhagen
ABSTRACT	We present scanning data of the first membrane-based scanning force microscope. The excellent force sensitivity in the atto-Newton range and the very low non-contact friction we measured, make this membrane-based scanning force microscope design a promising candidate for ultrasensitive measurements. Furthermore, we present our future plans for enhancing the readout, which should bring us closer to the final goal of 3D imaging of single viruses with magnetic resonance force microscopy (MRFM).

FNS 2021	POSTER 30
TITLE	**Eigenvalue Braiding around the Trefoil Knot of Degeneracies Near a Triple Exceptional Point**
AUTHOR(S) & AFFILIATION(S)	P. A. Henry, Y. S. S. Patil, J. Höller, C. Guria, Y. Zhang, L. Jiang, N. Kralj, N. Read, and J. G. E. Harris
ABSTRACT	Optomechanics has been used to explore the behavior of systems near exceptional points (EP's). Here, we use optomechanics to control three mechanical modes of a silicon-nitride membrane inside a Fabry-Perot cavity. We use this control to explore the parameter space for which the modes are near a triply degenerate exceptional point (EP3). Near the EP3, we find that the double-degeneracies (EP2's) form a structure related to the trefoil knot. We also find that the trajectories of eigenvalues along closed loops enclosing this knot realize the braid group B_3. We seek to use this knot to adiabatically transfer energy between eigenmodes.

FNS 2021	POSTER 31
TITLE	**Interrelation of elasticity and thermal bath in nanotube cantilevers**
AUTHOR(S) & AFFILIATION(S)	S. Tepsic1, G. Gruber1, C. Moller1, C. Magen2, P. Belardinelli3, E. Hernandez4, F. Alijani5, P. Verlot6, and A. Bachtold1 1ICFO, Castelldefels (Barcelona), Spain 2INMA & LMA, Universidad de Zaragoza, Zaragoza, Spain 3DICEA, Polytechnic University of Marche, Ancona, Italy 4ICMM-CSIC, Madrid, Spain 5TU Delft, Delft, The Netherlands 6The University of Nottingham, Nottingham, United Kingdom
ABSTRACT	We report the first study on the thermal behavior of the stiffness of individual carbon nanotubes, which is achieved by measuring the resonance frequency of their fundamental mechanical bending modes. We observe a reduction of the Young's modulus over a large temperature range with a slope − (173 ± 65) ppm/K in its relative shift. These findings are reproduced by two different theoretical models based on the thermal dynamics of the lattice. These results reveal how the measured fundamental bending modes depend on the phonons in the nanotube via the Young's modulus. An alternative description based on the coupling between the measured mechanical modes and the phonon thermal bath in the Akhiezer limit is discussed.

FNS 2021	POSTER 32
TITLE	**Phonon localization in 1D quasiperiodic systems**
AUTHOR(S) & AFFILIATION(S)	Priya, E. R. Cardozo de Oliveira, A. Rodriguez, O. Ortiz, M. Esmann, N. D. Lanzillotti-Kimura Centre de Nanosciences et de Nanotechnologies,10 Boulevard Thomas Gobert, 91120 Palaiseau, France
ABSTRACT	Quasiperiodic systems are known to engineer 1D localization of waves. There exists a variety of quasi-periodic models that lead to localized states and gaps of topological character. We have implemented the interpolating Aubry-Andre Fibonacci (IAAF) model and Cantor model to study localization effects on phononic modes in 1D quasiperiodic structures in the range of 20-100 GHz. The localized acoustic modes are generated due to on-site potential modulation obtained by alternating layers with different acoustic parameters.