MEMS and NEMS Group
Room A210 - Session MN+QS-TuA

Devices for Quantum Information and Quantum Nanomechanics

Moderators: Sebastian Hentz, CEA-LETI, France, Matthew Jordan, Sandia National Laboratories

2:20pm **MN+QS-TuA-1 Fabrication Challenges in Quantum Optomechanics*, Simon Groeblacher,*** Delft University of Technology, The Netherlands, Netherlands **INVITED**

Mechanical systems have recently attracted significant attention for their potential use in quantum information processing tasks, for example, as compact quantum memories or as transducers between different types of quantum systems. Recent advances have allowed to demonstrate non-classical behavior of mechanical motion by coupling a micro-fabricated acoustic resonator to single optical photons. These experiments include the heralded generation and on-demand readout of single phononic excitations, as well as entanglement between two mechanical modes.

Here we would like to discuss how we fabricate the optomechanical crystals used in these quantum experiments, which feature engineered mechanical resonances in the Gigahertz regime that can be addressed optically from the conventional telecom band. We will also show some of the challenges that need to be overcome in order to realize useful devices for real-world quantum information processing applications.

3:00pm **MN+QS-TuA-3 Floquet Dynamics and Time Symmetry Breaking in Arrays of Driven Nanoresonators*, Mark Dykman,*** Michigan State University **INVITED**

Periodically driven modes of nanomechnical resonators and electromagnetic cavities allow one to study peculiar features of quantum dynamics related to the discrete time translation symmetry imposed by the driving. For modes with high quality factors, which are typically studied in the experiment, these features become pronounced already for comparatively weak driving, provided it is resonant. Quantum dynamics of driven modes is described in terms of the Floquet states. Generally, if the system is in a Floquet state, its dynamical variables oscillate with the period of the driving. However, the discrete time-translation symmetry can be broken, leading to what is called the time crystal effect. For arrays of coupled vibrational modes, the symmetry breaking can occur both in the coherent and dissipative regimes. In the both regimes the transitions are induced by quantum fluctuations, making them nonequilibrium quantum phase transitions. However, the coherent and dissipative transitions are very different. The structure of the emerging states strongly depends on the disorder in the resonator arrays. We will discuss the transitions for the modes driven parametrically close to twice their eigenfrequency and also for the modes driven close to triple the eigenfrequency. Along with the theory we will discuss the ways of observing the vibrational time crystals in the experiment.

4:20pm **MN+QS-TuA-7 Engineering Quantum Signal Transduction in Atomic Layer 2D Devices*, Philip Feng,*** Case Western Reserve University **INVITED**

An essential theme of the ongoing ‘second quantum revolution’ is to realize human-made structures and devices where ‘quantum phenomena’ can be sustained and harnessed to enable radically new approaches to information processing. These require exquisite creation and scalable fabrication of atom-like devices, design and engineering of new information carriers and transduction schemes. Atomic layer crystals have emerged as attractive enablers for creating atomically thin 2D devices that can support signal transduction and information processing functions in the regime where classical meets quantum. In this presentation, we will report on our latest effort and results on developing novel 2D devices (including nanomechanical and photonic resonators, phononic waveguides, photodetectors, etc.), investigating quantum emitters and coupling effects on relevant 2D device platforms, and engineering both classical and quantum signal transduction schemes in such 2D devices and systems.

5:00pm **MN+QS-TuA-9 Superconducting Resonators as Diagnostics for Qubit Fabrication*, Rupert Lewis,*** Sandia National Laboratories **INVITED**

Quantum bits (qubits) fashioned from superconducting thin films and Josephson junctions require different fabrication approaches than back-end-of-the-line semiconductor fab. This

point is driven home most clearly by the realization that the qubit as an anharmonic singlephoton

microwave resonator. The presence of single photon in the qubit represents a one, the

absence represents a zero, thus if the photon is lost, the quantum state is also lost. In

consequence, fabricators of qubits go to extremes to provide low microwave loss environments

for their qubits. Planar microwave resonators—of the multiphoton variety—are an invaluable

diagnostic tool for assessing loss mechanisms in qubit fabrication and the quality of processes

used. This presentation will give a general overview of superconducting qubits and fabrication

techniques and how microwave resonators improve qubits.

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contract DE-NA-0003525.

5:40pm **MN+QS-TuA-11 Surface Ion Trap Device Fabrication for Experiments in Quantum Information Science*, Matthew Blain,*** Sandia National Laboratories **INVITED**

Radio-frequency (rf) surface ion traps offer important advantages for realizing precise control of the spatial positioning, as well as motional and electronic states, of trapped ions. The control of ions provided by micro-fabricating planar trap electrodes on a silicon device surface has allowed ion trapping to be at the forefront of experiments in quantum sensing, simulation, and information processing. Engineered surface traps offer the ability to extend the performance of their macroscopic equivalents and can even allow new concepts to be explored in both classical and quantum trapped-ion physics and chemistry. T he ability to fabricate complex and arbitrarily arranged 2-D and 2.5-D trap electrode geometries is critical for numerous trapped ion quantum information science experiments. Surface electrode ion traps [1] have enabled the Kielpinski ion trap CCD (charge coupled device) architecture [2], whereby ions can be shuttled between linear trapping regions via junctions, as well as trap designs, for example triangles [3] or rings [4], optimized for different experimental objectives. The ability to design and fabricate precision through-chip holes for ion loading and photon collection/delivery and to arbitrarily shape trap chips for increased optical access to ions is also critical for rendering a highly evolved ion trap chip technology. As well, micro ion trap chip technologies are beginning to integrate passive and active electronic and photonic capabilities for enhanced performance, including trench capacitors, optical waveguides, and avalanche photodiodes. Aspects of the “micro-systems” approach to the design and integration of surface electrode ion trap devices will be presented.

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[1] D L Moehring, *et al.*, *New Journal of Physics*, 13 (2011) 075018

[2] D Kielpinski, *et al.*, *Nature*, 709, 417(2002)

[3] M Mielenz, *et al.*, *Nature Communications*, 7 (2016) 11839

[4] B Tabakov, *et al.*, *Physical Review Applied*, 4 (2015) 31001

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