NCMN EQUATE
Emergent Quantum Materials and Technologies

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Quantum and Nonlinear Magnonics

ABSTRACT

As we progress more deeply into the second quantum revolution, a natural question we ask is – is there a role for magnonics in quantum information platforms? Building on a decade of foundational work on this progress, I will discuss my take on this question and our efforts to develop new the roles for magnonics in quantum and classical technologies. For quantum technologies, a major challenge is mitigating loss, since loss is the enemy of quantum coherence. First, I'll describe our efforts to establish a scalable cavity magnonics platform based on the ultra-low loss organic-based magnet vanadium tetracyanoethylene V[TCNE]x. We demonstrate strong coupling with cooperativities exceeding 1000 and material damping in patterned films that competes with single crystal yttrium iron garnet (YIG) spheres [1]. I'll also discuss some of the material challenges, including the heterogenous integration of an air-sensitive material. We show that atomic layer deposition of alumina is an effective encapsulate that introduces negligible microwave loss [2]. Furthermore, I'll discuss our approach to a cavity-magnonics implementation of the optomechanical-type nonlinear Hamiltonian [3]. Using this nonlinear interaction, we theoretically show how driving magnons that are coupled to a microwave electromagnetic resonator can enable resonator cooling and quantum squeezing. Finally, I'll describe our recent working using scanning NV center probes to understand nonlinear harmonic generation of magnons in magnetic spin textures. We image harmonic generation within the local spin texture of Ni81Fe19/Pt bilayers to establish the microscopic mechanism of this phenomenon and its relationship to more familiar harmonic generation in nonlinear optics.

References:
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BIO

Fuchs earned his Ph.D. in Applied Physics from Cornell University in 2007 where he was led one of two teams to first demonstrate spin-transfer torque switching in magnetic tunnel junctions – a technology that later formed the write mechanism for modern magnetic random access memory technologies. Afterward, he moved to the University of California, Santa Barbara as a postdoctoral associate where he changed research topics to focus on spin dynamics of diamond nitrogen-vacancy (NV) centers. In 2011, he joined the Cornell faculty of Applied and Engineering Physics. In 2012 he received a Young Investigator Award from the Air Force Office of Scientific Research, in 2013 he received an Early Faculty Career Award from the National Science Foundation along with the Presidential Early Career Award for Scientists and Engineers, and in 2014 he received the Early Career Award from the Department of Energy. In 2025 he was elected a fellow of the American Physical Society and named the inaugural James R. Meehl Professor of Applied and Engineering Physics. Fuchs's current research group focuses on quantum interactions between spins, magnons, photons, and phonons in solid-state systems, drawing inspiration from atomic physics, condensed matter physics, and materials engineering. Fuchs uses NV centers for quantum sensors, including to study magnetic materials, devices, and dynamics. Recently, Fuchs has studied magnetism in the quantum limit at low temperature by strongly coupling low-damping magnetic materials to superconducting resonators. His group also pioneered the use of gigahertz lattice strain from diamond micro-electromechanical devices to manipulate the quantum states of diamond NV centers. Fuchs has explored these interactions to extend spin coherence, coherently engineer optical transitions, and enable new sensing modalities. In addition to diamond, Fuchs studies the optical properties of quantum emitters in other materials including gallium nitride and hexagonal boron nitride. Recently, Fuchs has become interested in materials for superconducting quantum circuits, especially new tunnel barrier materials for Josephson junctions.

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