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Mechanical Engineering Seminar Series

Demystifying the Quantum Paradigm using Acoustic Metamaterials – Phi-bits as Quantum Computing Acoustics Analogues

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VIRTUAL SEMINAR

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ME Seminar Zoom link (QR Code below)

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Abstract

Ensuring U.S. leadership in quantum information science (QIS) is a national priority. While the phenomenon of entanglement is at the core of future QIS technologies and an attribute of quantum mechanics (QM), the notion of “classical entanglement” has recently emerged. “Classical entanglement” possesses the non-separability and related complexity that are essential to reach the promise of parallelism in quantum computing, but not the nonlocal aspect of quantum entanglement. A multipartite classical system is in a non-separable state when its parts are strongly correlated, and any change imposed on one part affects all the other parts. Such nonseparability creates the possibility of operating on the superpositions of states of a multipartite system in a parallel manner. Non-separability of classical waves offers the parallelism of quantum superposition of states used in quantum computing yet without the fragility of decoherence. Indeed, while quantum wave functions (probability amplitude) collapse upon measurement or due to thermal fluctuations necessitating cryogenic conditions, classical wave functions (amplitudes) are measurable and remain coherent at room temperature. We introduce the notion of ‘phase-bits’ or ‘phi-bits’ in acoustic metamaterials. Specifically, a logical phi-bit associates with a two-state degree of freedom of a nonlinear acoustic wave, which can be in a coherent superposition of states with complex amplitude coefficients. Therefore, phi-bits are classical analogues of qubits, the critical components of quantum computers. We have shown very recently that the strong coupling and nonlinearity of acoustic waves are a new way to realize the non-separable superpositions of phi-bit states spanning exponentially complex spaces, in a prerequisite to develop algorithms that exploit the computational parallelism arising from non-separability. In this presentation, we will demonstrate using a combination of experimental and theoretical approaches: 1) the exponentially complex scalable spaces of states (Hilbert space) of multiple phi-bits; 2) the non-separability of their coherent superpositions, and 3) operability on these states. This demonstration is using a physical platform constituted of a metamaterial comprising arrays of externally driven, nonlinearly coupled acoustic waveguides. This work opens pathways to promising and validated modes of storing, processing, and retrieving information that should compare favorably with state-of-the-art quantum systems without suffering from quantum fragility.

Bio

Pierre A. Deymier is a professor of materials science and engineering at the University of Arizona. He is also a faculty member in the BIO5 Institute, biomedical engineering program, and applied mathematics graduate interdisciplinary program. Deymier received his Ph.D. from the Department of Materials Science and Engineering at the Massachusetts Institute of Technology in 1985 and subsequently joined the University of Arizona.

Deymier has a wide range of interests in the field of materials science and engineering, including materials theory, modeling, and simulation, the emerging field of acoustic metamaterials and phononic crystals, and topological acoustics, as well as biomaterials. He is the author or co-author of more than 280 scholarly products. He is the editor, author, or co-author of three books: P.A. Deymier Ed., “Phononic crystals and acoustic metamaterials,” Springer Series in Solid-State Sciences, 173, Springer, Berlin, (2013); P.A. Deymier, K. Runge and K. Muralidharan (Co-Eds) “Multiscale Paradigms in Integrated Computational Materials Science and Engineering,” Springer Series in Materials Science, 226, Springer, Berlin, (2015); and P.A. Deymier, K. Runge, “Sound Topology, Duality, Coherence, and Wave-Mixing: An Introduction to the Emerging New Science of Sound,” Springer Series in Solid-State Sciences, 188, (2017)

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