Mechanical Engineering Seminar

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Topological Vibroacoustic Metamaterials for Low-Frequency Sound Manipulation at the Subwavelength Scale

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The ability to manipulate low-frequency sound is essential due to its significant societal, environmental, and technological implications. Low-frequency sound, characterized by long wavelengths and weak damping, exhibit strong diffraction and penetration, making them persistent and challenging to control. Acoustic metamaterials, which typically rely, either directly or indirectly, on Bragg diffraction, require periodic structures on scales comparable to the wavelength. This restricts their application to ultrasonic frequencies or necessitates impractically large structures for audible sound. In this seminar, I will introduce new sub-Bragg mechanisms that address these challenges, including the formation of genuinely subwavelength Bragg-like bandgaps, termed "band-splitting-induced bandgaps", and the widening of subwavelength local resonance bandgaps by incorporating multiple resonances within the same bandgap. These sub-Bragg phenomena are realized in vibroacoustic metamaterials featuring multilayered unit cells composed of membrane-cavity resonators. I will discuss the physical principles underlying these mechanisms, their implications for acoustic performance, and an unexpected breakdown of classical geometric Bragg diffraction. Additionally, I will present findings on the formation, evolution, and robustness of subwavelength topological interface states within these vibroacoustic metamaterials, providing exact expressions for their locations as predictive design tools. Finally, I will showcase ongoing efforts in the design, fabrication, and testing of the membrane-based vibroacoustic metamaterial. By combining vibroacoustic metamaterials with topological physics, this work opens new avenues for compact, robust, and high-performance acoustic devices, transforming sound-wave manipulation at the subwavelength scale.

Majdi Gzal is a second-year postdoctoral scholar in the Department of Mechanical Science and Engineering at the University of Illinois Urbana-Champaign. He earned his B.Sc. and Ph.D. (direct track) from the Faculty of Mechanical Engineering at the Technion – Israel Institute of Technology. His research focuses on acoustics, structural dynamics, vibroacoustic metamaterials, topological metamaterials, and nonlinear dynamics and vibrations, as well as nonlinear waves.

Seminars Coordinator: Assoc. Prof. Gal Shmuel