Short course: Piezoelectric energy harvesting

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Abstract: Energy harvesting from dynamical systems offers the possibility of enabling self-powered wireless electronic components, such as low-power sensors in a plethora of current and future applications of the Internet of Things, from wearable electronics to civil structures. Piezoelectric energy harvesting is arguably the most popular method in this context. This course will cover methods of piezoelectric energy harvesting with examples from two decades of literature. Following a brief review of the basic concepts and lumped-parameter electromechanical representation, the standard problem of vibration-based energy harvesting using piezoelectric transduction will be discussed for AC and DC power generation scenarios. The extension of such lumped-parameter approaches to distributed-parameter systems will also be summarized. Performance and bandwidth enhancement in piezoelectric energy harvesting by leveraging intentionally introduced nonlinearities will be covered next. Specifically, monostable and bistable Duffing oscillator configurations will be reviewed with various examples from the literature, along with select modeling techniques, such as the use of the method of harmonic balance. Inherent material and dissipative nonlinearities, as well as circuit nonlinearities, will also be summarized. Aeroelastic and hydroelastic energy harvesting techniques will be reviewed for converting fluid flow into electricity. Examples will be detailed on leveraging the classical flutter and axial flow-induced nonlinear limit cycle oscillations. Finally, recent developments in the domain of exploiting metamaterial and phononic crystal concepts in energy harvesting will be addressed with select examples of energy harvesting combined with structure-borne elastic wave focusing and bulk acoustic wave focusing, as well as with locally resonant metamaterials. **Outline: (1)** Aeroelastic and hydroelastic energy harvesting (flow energy harvesting via classical flutter, vortex-induced vibrations, nonlinear limit-cycle oscillations under axial flow, etc.); **(2)** Metamaterial and phononic crystal concepts (acoustic/elastic wave energy focusing, gradient-index and graded concepts, multifunctional concepts with bandgap formation, etc.)

Bio: Prof. Alper Erturk is the Carl Ring Family Chair in the Woodruff School of Mechanical Engineering at Georgia Tech, where he leads the Smart Structures & Dynamical Systems Lab. His theoretical and experimental research interests are in dynamics, vibration, and acoustics of passive and active (smart) structures for various engineering problems. He has published 120 journal papers, 130 conference proceeding papers, 5 book chapters, and 2 books (total citations > 19,000 and h-index: 60). He is a recipient of various awards including an NSF CAREER Award in Dynamical Systems, ASME C.D. Mote Jr. Early Career Award for “research excellence in the field of vibration and acoustics”, ASME Gary Anderson Early Achievement Award for “notable contributions to the field of adaptive structures and material systems”, SEM James Dally Young Investigator Award for “research excellence in the field of experimental mechanics”, and numerous best paper awards including the Philip E. Doak Award of the Journal of Sound and Vibration, and two ASME Energy Harvesting Best Paper Awards, among others. He is an Associate Editor for various journals such as Smart Materials & Structures and ASME Journal of Vibration & Acoustics. He holds Invited/Adjunct Professor positions at Politecnico di Milano (POLIMI) and at Korea Advanced Institute of Science and Technology (KAIST). He is a Fellow of ASME and SPIE.