Contribution ID: **1344** Type: **2016 DCMMP PhD Thesis Award Competition**

Ultrasonic waves in strongly scattering disordered media: understanding complex systems through statistics and correlations of multiply scattered acoustic and elastic waves.

Wednesday 15 June 2016 13:15 (30 minutes)

The study of classical wave transport in strongly scattering, disordered media is a field rich with potential for understanding new fundamental wave physics phenomena, understanding the physical properties of amorphous materials, and probing the characteristics of complex, real-world systems. In this thesis, ultrasonic wave transport in complex media is investigated via analysis of the multiply-scattered transmitted field. In the strong-scattering regime, wave interference effects give rise to interesting physical phenomena, such as Anderson localization, which for electron transport was awarded the Nobel prize, and infinite-range C_0 correlations. The results presented provide the first experimental determination of the mobility edge and critical exponent ν that characterize the Anderson transition for classical waves. Additionally, infinite-range C_0 correlations have for the first time been directly observed [1], and found to grow dramatically near the mobility edge, along with the C_2 and C_3 correlations. Measurements of the multifractal exponent Δ_2 demonstrated the link between C_0 correlations and Anderson localization. The density of states and level-spacing statistics are two underlying properties that affect wave transport in amorphous materials. Direct measurements of these quantities were obtained using small samples, allowing individual vibrational modes to be resolved [2]. The density of states showed a plateau extending well into the expected Debye regime, and evidence of a Boson peak was observed at low frequencies. The level-spacing statistics indicated that transport in the frequency ranges measured was on the diffusive side of the mobility edge, providing experimental evidence that the Boson peak need not result from localized modes. Multiply scattered classical waves also provide a useful tool for characterizing disordered systems. In this work, the dynamics of a suspension of bubbles were investigated using phase-based Diffusing Acoustic Wave Spectroscopy, where a new approach using phase correlations was shown to give additional information beyond that obtainable from traditional methods.

[1] W.K. Hildebrand, A. Strybulevych, S.E. Skipetrov, B.A. van Tiggelen, and J.H. Page, Phys. Rev. Lett. **112**, 073902 (2014).

[2] W.K. Hildebrand, L.A. Cobus, and J.H. Page, J. Acoust. Soc. Am. **127**, 2819 (2010).

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Session Classification: W2-6 DCMMP PhD Thesis Award Competition / Compétition du Prix de thèse doctorale DPMCM

Track Classification: Condensed Matter and Materials Physics / Physique de la matière condensée et matériaux (DCMMP-DPMCM)