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New Insights on Coherent Wave Transmission through Disordered Systems

Stefan ROTTER
Institute of Theoretical Physics, Vienna University of Technology, Austria

Abstract:

I will report on recent projects focused on the coherent scattering of waves in disordered media or at corrugated surfaces. In the first part of my talk I will speak about our theoretical and experimental studies on microwave scattering through systems which are so strongly disordered, that the effect of Anderson localization suppresses all but a single transmission channel [1]. As a result, we can describe the entire disordered sample in this deeply localized limit as an effective 1D system with a renormalized localization length. We show that the dominant transmission channel is formed by an individual Anderson-localized mode or by a so-called "necklace state". Using pulsed excitations of the disordered samples allows us to identify long-lived localized modes and short-lived necklace states at long and short time delays, respectively.

In a second project, we study the wave transmission through wave guides with surface corrugations [2,3]. We show that for a quantitatively accurate description of such a situation, scattering processes need to be taken into account which are of higher order in the surface corrugation amplitude than those which are conventionally considered. Including these higher-order terms, we are able to provide fully analytical expressions for the multi-mode wave guide transmission which are in excellent agreement with independently obtained numerical results [2]. Based on this comprehensive approach we find and explain pronounced reflection resonances in wave guides with a step-like surface profile - a robust effect which has been overlooked in previous studies of the same system. I will also explain how these insights allow us to design wave guides with transmission band gaps in predetermined frequency intervals [3].

In the last part of my talk I will explain how surface-disordered mirrors can be used to study ultra-cold neutrons bouncing in the gravitational field of the earth [4]. The quantized energy levels of these gravitationally bound neutrons can be employed for gravity resonance spectroscopy - a new technique to measure the law of gravity at short distances which is accurate enough to provide stringent constraints on certain scenarios for deviations from the Newtonian law of gravity.

[1] Pena A, Girschik A, Libisch F, Rotter S, and Chabanov A A 2014, Nature Commun. 5 3488
[2] Doppler J, Mendez-Bermúdez J A, Feist J, Dietz O, Krimer D O, Makarov N M, Izrailev F M, and Rotter S 2014, New J. of Phys. 16 053026
[3] Dietz O, Stockmann H-J, Kuhl U, Izrailev F M, Makarov N M, Doppler J, Libisch F, and Rotter S 2012, Phys. Rev. B 86 201106(R)
[4] Jenke T et al. 2014, Phys. Rev. Lett. 112 151105 (selected for Nature News, Physics Viewpoint, PRL Editors' suggestion)