MAX PLANCK INSTITUTE
FOR THE STRUCTURE AND DYNAMICS OF MATTER

# ANNOUNCEMENT - TALK

Title: **Coherent Control of Wave Scattering via Tunable Chaotic Cavities**

Abstract:
Controlling multiple scattering of waves in higher dimensional geometries has been an area where analytic methods and mathematical insight has been lacking, and black-box optimization is considered the only viable approach. Surprisingly, a new theoretical approach to solving such problems has come from laser physics and, specifically, from time-reversed lasing, or Coherent Perfect Absorption. The theory of Coherent Perfect Absorption[1] (CPA), and its extension to Reflectionless Scattering Modes[2] (RSM), has shown that there do exist discrete scattering solution for all linear waves, in arbitrarily complex geometries, that achieve important control functions: perfect transduction (CPA) and perfect impedance matching (RSM). Generically, these solutions are at complex frequency and are only accessible transiently; but with tuning of two system parameters, they can be realized in steady-state at a given real frequency. Here we characterize the complete set of such functionalized scattering solutions at complex frequency, of which CPA and RSM are a subset, all of which can be tuned to become steady-state solutions. We show theoretically[3] how even more highly constrained control functions can be achieved, such as routing or demultiplexing, using these solutions as building blocks. We present simulations and experiments focused on tunable microwave cavities, but the conceptual framework is completely general and applies to quantum matter waves as well.
For heuristic reasons we expect an open low-loss wave-chaotic cavity with tunable scattering elements to be optimal for achieving control and routing of input waves, since such a cavity has overlapping, pseudo-random resonances, making it frequency agnostic, and easily reprogrammable. We will present the results of recent experiments[4] and simulations[3,4] of such a cavity that have confirmed the efficacy of this approach in the microwave frequency range. Since these systems are easily reprogrammable and flexible, they are robust to perturbations and to fabrication defects, and they have the potential to be uniquely effective for applications where frequency-agile functioning is required.

1. "Coherent Perfect Absorbers: Time-reversed Lasers", Y.D. Chong, L. Ge, H. Cao, and A. D. Stone, Physical Review Letters, 105, 053901 (2010).
2. "Theory of Reflectionless Scattering Modes", William R. Sweeney, Chia Wei Hsu, and A. Douglas Stone, Phys. Rev. A, 2020, https://link.aps.org/doi/10.1103/PhysRevA.102.063511
3. "Coherent Control of Scattering of Waves via Engineering of Complex Spectra", in preparation, A. Alhulaymi, N. Pyvovar, P. Del Hougne, O. D. Miller, A. D. Stone.
4. "Agile Free-Form Signal Filtering and Routing with a Chaotic-Cavity-Backed Non-Local Programmable Metasurface", F. T. Faul, L. Cronier, A. Alhulaymi, A. D. Stone, P. del Hougne, Advanced Science, DOI: 10.1002/advs.202500796.

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| Date/Time: | **FRIDAY, JUNE 6th at 11:00** |
| Location: | **MPSD 900.EG.136** |
| Speaker: | **A. Douglas Stone** |
| Affiliate: | **Yale University, Dept of Applied Physics** |