Quantum Transport in Chaotic and Disordered Systems

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Quantum transport in complex quantum systems is an intriguing and highly non-trivial subject of utmost relevance in many branches of the fundamental and applied sciences. Examples range from simple decay processes and the relevant part of scattering theory which comes with it, over the quantum dynamics in mixed regular-chaotic phase spaces and on irregular graphs, weak and strong localization of photons or ultracold matter in disordered scattering media, excitation transport in cold Rydberg gases and biomolecules, to micro-resonators, random lasers, and the metal-insulator transition.

In this lecture series, I will try to develop a unified perspective on these various issues. Starting out from fundamental tunneling phenomena, we will dive into classically mixed regular-chaotic phase space, and discuss the signatures of this intricate structure in the time evolution of a quantum state. We will see that these in some respects bear close analogies to hallmarks of quantum transport in disordered systems, with Anderson localization as the most prominent feature, but that the mixedness of phase space adds additional features which are absent in disordered systems - e.g. chaos- and resonance-assisted tunneling. We will discuss the relevance of these different phenomena for complex quantum systems as realized, e.g., by ultracold atomic gases loaded into engineered potential landscapes, multiple scattering of light from cold atomic clouds, interacting Rydberg gases or, possibly, in the light harvesting complex of photosynthesis.