Controlling modes and delay times in complex systems for enhanced light-matter interaction.

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Very significant progress has been made in the field of wavefront shaping during the last 10 years [1]. It has especially been demonstrated that transmission through a complex system can be controlled over a wide dynamic range by exciting transmission eigenchannels of the transmission matrix. It has been proposed recently that controlling the delay time of scattered waves may offer new perspectives to excite particle-like states [2, 3] or enhance energy storage within complex systems [4].

In this talk, I will consider our ability to enhance light-matter interaction by coherently controlling an incident wavefront. I will first show that a modal analysis of the transmission matrix in samples with moderate modal overlap makes it possible to enhance the energy of a mode by a factor equal to the number of channels [5]. This is achieved by decomposing the TM as a superposition of rank one matrices associated to quasi-normal modes of the system. The non-orthogonality between speckle patterns in non-Hermitian systems however limits modal selectivity [5, 6].

Controlling QNMs is however not possible in strongly open systems since the contribution of non-resonant terms precludes modal analysis. I will then demonstrate that maximizing the coupling between the incident wavefront and a resonator is possible by coherently controlling the delay time of transmitted or reflected waves. The optimal wavefront is found by exciting the eigenstate of the Wigner-Smith operator associated to the largest delay time.

These two techniques for enhanced light-matter interaction are demonstrated in microwave measurements in multichannel disordered waveguides. Maximized excitation of QNMs is first illustrated in the spatial distribution of the field. Enhanced energy stored in multiple high-permittivity dielectric scatterers and extended leaky cavities is then demonstrated *in-situ* by injecting optimal wavefronts using IQ modulators. We expect our results to impact the fields of photonic-energy harvesting and optical imaging in scattering media.

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