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Coherent Optics for Energy Transfer, Storage and Release

Light absorption underlies several optical functionalities, including sensing, photovoltaics and energy transfer. Coherent perfect absorption (CPA),¹ the time-reversed version of lasing, has enabled efficient control of light absorption by exciting a scattering-matrix zero (SZ) located on the real frequency axis (see figure). By controlling the coherence and relative phase of counterpropagating beams exciting the absorber, it is possible to use this phenomenon to realize efficient optical switches and logic gates.²

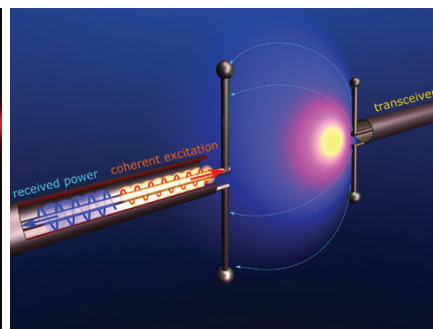
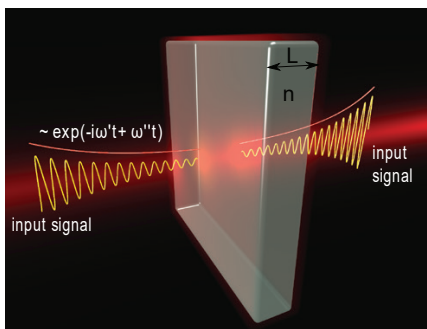
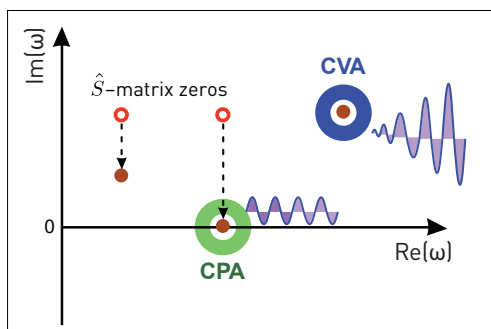
Interestingly, exploiting coherence to control optical phenomena offers far richer opportunities beyond enhancing absorption. We have recently shown that it is possible to induce CPA-like responses in lossless systems, engaging SZs in the complex frequency plane rather than on the real axis and thereby creating mechanisms for storing and releasing light.³

Instead of exciting the structure with monochromatic signals, we tailor the incident field in time such that its temporal profile matches the exponentially growing fields associated with a complex zero. During this period, the scattering from the structure totally vanishes, as if the structure were perfectly absorbing, despite the fact that it does not support loss or absorption. Rather than converting light into other forms of

energy, the system stores it with unitary efficiency. When the excitation is stopped, or the relative phase of the impinging waves is modified, the stored energy can be released on demand.

We refer to this mechanism as coherent virtual absorption (CVA),³ which may be used for efficient light storage and release in nanophotonic integrated devices. Analogously, coherent excitations can be used to enhance and control energy transfer.⁴ A typical wireless power transfer system consists of a transmitting and a receiving transducer connected through a wireless channel. This commonly requires accurate design and arrangement of the entire system to ensure maximized energy transfer, and modifications of the channel between the antennas or misalignments can largely affect the overall efficiency.

We have shown that, by coherently exciting the receiving antenna with an auxiliary signal, tuned in sync with the impinging signal from the transmitting antenna, it is possible to largely enhance the robustness of the system and maximize its efficiency.⁴ This additional signal enhances energy transfer through constructive interference with the impinging wave, compensating any imbalance in the antenna coupling without having to modify the load. **OPN**



Left: S-matrix zeros in the complex frequency plane for a lossless (hollow circles) and lossy (filled circles) slab. Wavy curves show the signal form needed to engage scattering-matrix zeros. Center: Coherent virtual absorption in a planar dielectric slab illuminated by counterpropagating beams. Right: Coherently enhanced wireless power transfer: transmitting (right) and receiving (left) transducers driven by an additional wave sent from the load (red wave). [Adapted from references 3 and 4.]