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Directionality in engineered quantum systems

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Reciprocity is a fundamental symmetry in physics; in optics it can be understood as the principle of 'if I can see you, you can see me'. Breaking this symmetry results in asymmetric information transfer between two systems, i.e., the transmission amplitudes change under the exchange of source and detector. In the ptimal situation, information transfer only occurs in one direction, which is a highly valuable feature for quantum information processing, where one aims to read out a quantum system while protecting the signalource. The violation of the symmetry of reciprocity requires rather special conditions, and one may ask the question if there is a general way to break reciprocity between two systems. This is indeed possible, we find that one can construct nonreciprocal interactions by combining the appropriate coherent and dissipative dynamics. Our nonreciprocity concept was experimentally confirmed within an optomechanical array setup in a collaboration with Oscar Painter's group at Caltech. Furthermore, a number of related experiments can essentially be mapped to our approach as well. Overall, the nonreciprocity protocol is a powerful tool for realize directional interactions between two quantum systems and its full potential has yet to be explored. In this talk I give an introduction of the basic concept on how to engineer nonreciprocal interactions and devices. Furthermore, I present possible implementations in superconducting circuit and optomechanical architectures and give an outlook about how directionality in engineered quantum systems can be of relevance for the processing and storage of quantum information, as well as for the unraveling of sensitive fundamental knowledge of systems in the quantum regime.