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Scientists experimentally realize optomechanically induced non-reciprocity

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Light has reciprocity with bidirectional transmission in ordinary media. Circulators and isolators are indispensable components in classical and quantum information processing in an integrated photonic circuit. Therefore, all-optical controllable non-reciprocal devices are always a hot topic in the research of photonic chips. Normal non-reciprocal devices are based on magnetic-optical material. However, incorporating low optical-loss magnetic materials into a photonic chip is technically challenging.

DONG Chunhua's group and ZOU Changling from the Chinese Academy of Sciences first experimentally demonstrated non-magnetic non-reciprocity using optomechanical interactions in a whispering gallery microresonator. This work was published in *Nature Photonics*.

This study utilizes ordinary optomechanical interaction in whispering gallery microresonators, where the two optical modes are the degenerate clock-wise (CW) and counter-clockwise (CCW) traveling-wave whispering-galley modes with opposite orbital angular momentums. For such an interaction, the CW and CCW modes are independently coupled with the mechanical mode.

Because of the conservation of orbital angular momentum, the driving field can stimulate coherent interaction between signal photons and phonons only when the driving and signal optical fields are coupled to the same optical mode. As a result, the directional driving field breaks the time-reversal symmetry and leads to non-reciprocal transmittance for the signal light.

Optomechanically induced non-reciprocal transparency (OMIT) and amplification (OMIA) are observed, and a non-reciprocal phase shift of up to 40 degrees is demonstrated in this study. Optomechanically induced non-reciprocity is actually controllable using two oppositely propagating driving fields that excite the CW and CCW modes simultaneously, which behaves as a controllable narrowband reflector with nonreciprocal transmittance.

Note that the underlying mechanism of non-reciprocity demonstrated in this study is actually universal and can be generalized to any traveling wave resonators via dispersive coupling with a mechanical resonator. With the mechanical vibrations being cooled to their ground states, applications in the quantum regime, such as single-photon isolators and circulators, also become possible.

Aside from these applications, non-reciprocal phase shift is of fundamental interest for exploring exotic topological photonics, such as the realization of chiral edge states and topological protection.

The results of this study represent an important step toward integrated all-optical controllable isolators and circulators, as well as non-reciprocal phase shifters.

This work is an extension of last year's research by DONG's group regarding Brillouin scattering non-reciprocity (*Nature Communications*), which expanded the applications of non-reciprocal devices based on cavity optomechanics to the whole optical wavelength or even the microwave wavelength. Especially when the system is in the ground state, single-photon isolators and circulators could also lead to hybrid quantum Internet technology.

More information: Zhen Shen et al, Experimental realization of optomechanically induced non-reciprocity, *Nature Photonics* (2016). DOI: 10.1038/nphoton.2016.161

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