New theory shows one-way transmission materials should be possible for sound and light waves

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(PhysOrg.com) -- Physicist Stefano Lepri of the Italian National Research Council and his partner Giulio Casati of the University of Insubria, have published a paper in *Physical Review Letters*, where they demonstrate through mathematical theory that it should be possible to create asymmetric materials that allow most light or sound waves to pass through in one direction, while mostly preventing them from doing so when going the opposite way.

Scientists have for years been trying to figure out if it was possible to get around the reciprocity theorem, which states that identical waves passing through the same medium should behave the same way regardless of direction. If such a feat were possible, true one-way mirrors could be created, or soundproof rooms, or taking it further, quantum computers that use light to perform calculations.

Lepri and Casati, in their paper, propose the idea of constructing a material composed of several layers of ordinary linear material, such as glass or plastic, but that also has two nonlinear layers of material in the center. They then showed that because waves travel best through material when their frequency has a certain resonance with the material it passes through, it should be possible to create a nonlinear material that is fine tuned to allow the maximum amount of waves to pass through for a certain frequency, going a certain direction; but which would not generally be the case for waves traveling in the opposite direction. The result would be a material that lets through most of the waves traveling in one direction, but not the other.

If such materials could be created, scientists envision not just custom building materials that could control how much heat or light comes through, while still allowing people to see out, or true one-way mirrors, or houses made with rooms that are nearly perfectly sound proof, but perhaps wave diodes that could be used in the same way as electronic diodes that allow current to run just one way through a system; paving the way for computers that operate at speeds we can only dream of today.

Neither Lepri and Casati, nor anyone else has yet come up with a nonlinear material that can be fine tuned to provide the custom resonance required to create such a material, however, so for now, this new science is still just theory; the authors believe it's just a matter of time though.

More information: Asymmetric Wave Propagation in Nonlinear Systems, *Phys. Rev. Lett.* 106, 164101 (2011)
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Abstract
A mechanism for asymmetric (nonreciprocal) wave transmission is presented. As a reference system, we consider a layered nonlinear, nonmirror-symmetric model described by the one-dimensional discrete nonlinear Schrödinger equation with spatially varying coefficients embedded in an otherwise linear lattice. We construct a class of exact extended solutions such that waves with the same frequency and incident amplitude impinging from left and right directions have very different transmission coefficients. This effect arises already for the simplest case of two nonlinear layers and is associated with the shift of nonlinear resonances. Increasing the number of layers considerably increases the

complexity of the family of solutions. Finally, numerical simulations of asymmetric wave packet transmission are presented which beautifully display the rectifying effect.