Building a Moebius strip of good vibrations

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Yale physicists have created something similar to a Moebius strip of moving energy between two vibrating objects, opening the door to novel forms of control over waves in acoustics, laser optics, and quantum mechanics.

The discovery also demonstrates that a century-old physics theorem offers much greater freedom than had long been believed. The findings are published online July 25 in the journal *Nature*.

Yale's experiment is deceptively simple in concept. The researchers set up a pair of connected, vibrating springs and studied the acoustic waves that traveled between them as they manipulated the shape of the springs. Vibrations—as well as other types of energy waves—are able to move, or oscillate, at different frequencies. In this instance, the springs vibrate at frequencies that merge, similar to a Moebius strip that folds in on itself.

The precise spot where the vibrations merge is called an "exceptional point."

"It's like a guitar string," said Jack Harris, a Yale associate professor of physics and applied physics, and the study's principal investigator. "When you pluck it, it may vibrate in the horizontal plane or the vertical plane. As it vibrates, we turn the tuning peg in a way that reliably converts the horizontal motion into vertical motion, regardless of the details of how the peg is turned."

Unlike a guitar, however, the experiment required an intricate laser system to precisely control the vibrations, and a cryogenic refrigeration chamber in which the vibrations could be isolated from any unwanted disturbance.

The Yale experiment is significant for two reasons, the researchers said. First, it suggests a very dependable way to control wave signals. Second, it demonstrates an important—and surprising—extension to a long-established theorem of physics, the adiabatic theorem.

The adiabatic theorem says that waves will readily adapt to changing conditions if those changes take place slowly. As a result, if the conditions are gradually returned to their initial configuration, any waves in the system should likewise return to their initial state of vibration. In the Yale experiment, this does not happen; in fact, the waves can be manipulated into a new state.

"This is a very robust and general way to control waves and vibrations that was predicted theoretically in the last decade, but which had never been demonstrated before," Harris said. "We've only scratched the surface here."

In the same edition of *Nature*, a team from the Vienna University of Technology also presented research on a system for wave control via exceptional points.

More information: Topological energy transfer in an optomechanical system with exceptional points, *Nature*, DOI: 10.1038/nature18604

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