A new metasurface model shows potential to control acoustic wave reflection

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An international team of researchers showed how a nonlinear elastic metasurface could convert a wave's fundamental frequency to its second harmonic. Structural factors in metasurfaces, like the spatial arrangement of its molecules and its composition, underpin its optical, elastic and acoustic properties. Developing this metasurface could help architects reduce noise from performance halls to cityscapes. These findings could also enhance cloaking technology for submarines to evade sonar detection.

Typically, when a soundwave strikes a surface, it reflects back at the same fundamental frequency with a different amplitude. Their model, reported in the *Journal of Applied Physics*, shows that when a sound wave hits this metasurface, the incident fundamental frequency does not bounce back. Instead, the metasurface converts that energy into the wave's second harmonic resonance.

Vincent Tournat, a senior research scientist in acoustics at France's CNRS and an author on the paper, explained that "you send a A440 pitch and after reflection, this is transformed into A880 pitch." He expounded that this wave conversion is possible "with a thin reflecting surface ... much less than the acoustic wavelength."

Tournat reports that they are among the first acoustics groups to study nonlinear acoustic metasurfaces. Their lab focuses on nonlinear acoustics, which describes high amplitude wave interactions with nonlinear elements or media. For example, this subfield studies how a sound interacts with cracks in a solid material, or how elastic waves interact with highly deformable structures.

The team developed their new metasurface concept from past experimental work. Previously, they printed soft rubber materials like PDMS, a silicon based polymer, arranged the components in rotating square configurations, and sent soundwave pulses through the structures. When pulses propagated through PDMS structures with a particular geometry, the researchers observed a strange effect: the propagation of solitons, stable nonlinear wave pulses. As a result, the highly deformable structure appeared as an ideal platform to design a specific elastic nonlinearity.

These metasurfaces could significantly advance noise control technologies because they could better isolate the main problem in noise control: low frequencies. "If you convert the energy to higher frequencies, then you can more easily absorb it later," Tournat said.

He also cites that thin metasurfaces could become components of more complex devices like acoustic diodes and transistors. These findings could even be applied to other types of waves. In optics, metasurfaces based on a similar concept "could replace second harmonic generation (SHG) crystals used to double the frequency of a laser in transmission," Tournat said.

These unexpected reflections are almost like a funhouse mirror for sound. "It would be analogous to look at you in a mirror and have a reflected image shifted in the ultraviolet optical range," Tournat said. Moving forward, the team now aims to build the metasurface and experimentally test their findings.

More information: Xinxin Guo et al, Manipulating acoustic wave reflection by a nonlinear elastic metasurface, *Journal of Applied Physics*

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