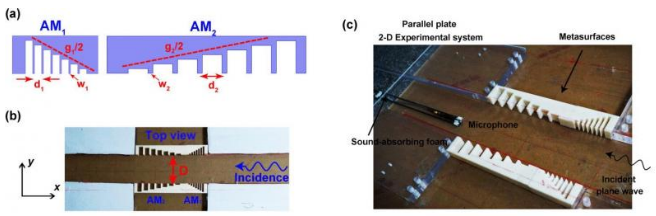
One-way sound tunnel offers novel way to control acoustic waves

30 September 2015, by Lisa Zyga



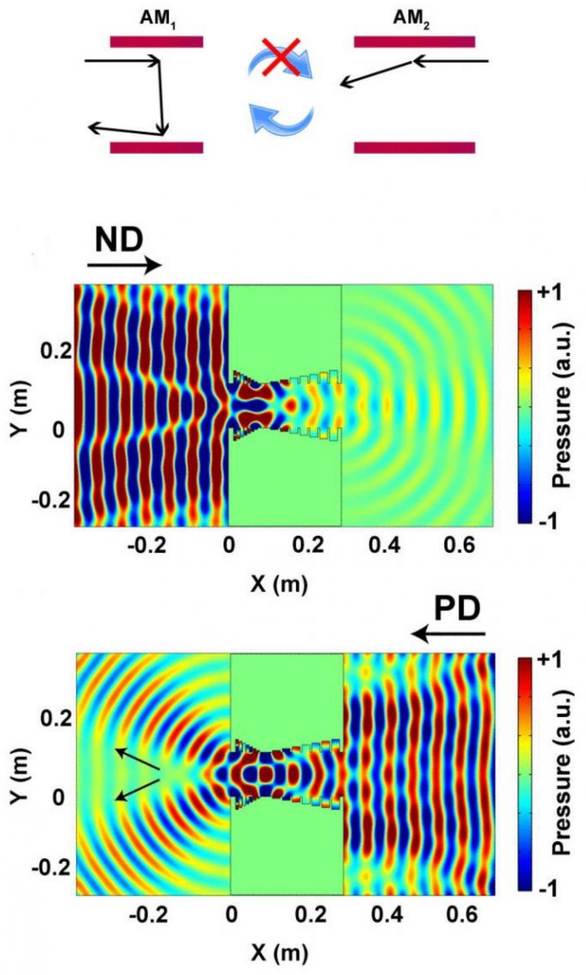
(a) The two acoustic metamaterials have different groove patterns, which are positioned at different sides of the tunnel so that they affect the sound waves differently depending on which direction they're coming from. (b) and (c) Photographs of the open tunnel. Credit: Zhu, et al. ©2015 AIP Publishing

(Phys.org)—Scientists have designed and built an acoustic one-way tunnel that allows sound to pass through in one direction only while blocking it from passing through in the opposite direction. The tunnel is completely open to light and heat, which can pass through in both directions, but sound waves are blocked in one direction due to acoustic metamaterials placed on the sides of the tunnel. The acoustic one-way tunnel has potential applications for anti-noise windows and vent ducts, as well as medical ultrasound.

The researchers, Yi-Fan Zhu, Xin-Ye Zou, Bin Liang, and Jian-Chun Cheng, from Nanjing University in China, have published their paper on the acoustic one-way tunnel in a recent issue of *Applied Physics Letters*.

"One-way acoustic devices are believed to have deep implications in various situations by breaking through the conventional concept that sound always propagates symmetrically along a given path," Liang told *Phys.org*, noting some of their previous related work here, here, and here. "The realization of an acoustic one-way tunnel goes further beyond simply breaking through this limitation, and enables one-way acoustic manipulation when the acoustic path is kept totally open to other entities. We envision our design with such novel capability and tunability to offer more design possibilities and have promising application potential in various scenarios where special manipulation of sound is desired."

The new tunnel takes advantage of the extraordinary reflection properties of recently developed acoustic metamaterials, which force sound waves coming from one direction to make a U-turn in the 10-cm-wide tunnel and travel back out. By strategically positioning two different acoustic metamaterials with different reflective properties along the insides of the tunnel, the researchers could asymmetrically manipulate the sound waves so that only those coming from one direction are reflected, while those coming from the other direction can pass through.



(Top) When an acoustic wave enters from the side of the tunnel with “acoustic metamaterial 1” (AM1), it makes a U-turn and reflects back out, whereas the majority of an acoustic wave traveling from the other side with “acoustic metamaterial 2” (AM2) can pass through. (Bottom) Simulated acoustic field patterns for the negative direction (ND) that does not allow acoustic wave passage and positive direction (PD) that does. Credit: Zhu, et al. ©2015 AIP Publishing

The researchers printed the acoustic metamaterials using a 3-D printer with ABS plastic, which is the same material used to make Legos. They then imprinted multiple tiny grooves into the two metamaterials with different groove periods (0.84 cm and 2.36 cm), which gives them different reflective properties. The tailored groove designs affect the sound waves differently depending on which direction they're coming from, which ultimately leads to the asymmetric wave manipulation and one-way transmission.

Although other methods have been developed for the unidirectional control of sound, all of the previous designs have relied on bulk materials. The drawback of bulk materials is that they partially block the tunnel so that it's not fully open to other entities, such as light and heat.

Because the new tunnel allows light and heat to freely pass through from both directions while blocking the transmission of sound in one direction, it could lead to anti-noise windows that are see-through and ventilated, and may inspire research into the unidirectional control of other kinds of waves.

"The acoustic one-way open tunnel may also enable conceptual devices like novel ventilating channels that block sound from one side but allow air or heat flow to pass freely, or serve as building blocks of more complex systems that reduce the reflected wave but do not affect the passage of other objects, which may find extensive applications in the fields of noise control or biomedical imaging/treatment, etc.," Liang said.

In the future, the researchers plan to improve the performance of the one-way open tunnel, for example by boosting the efficiency and broadening the bandwidth. They also want to devise methods for manipulating sound in even more unprecedented ways beyond the one-way manipulation demonstrated in the current work, while keeping the acoustic path fully open.

More information: Yi-Fan Zhu, et al. "Acoustic one-way open tunnel by using metasurface." *Applied Physics Letters*. DOI: 10.1063/1.4930300