Researchers achieve 3-D underwater acoustic carpet cloak with 'Black Panther'-like features

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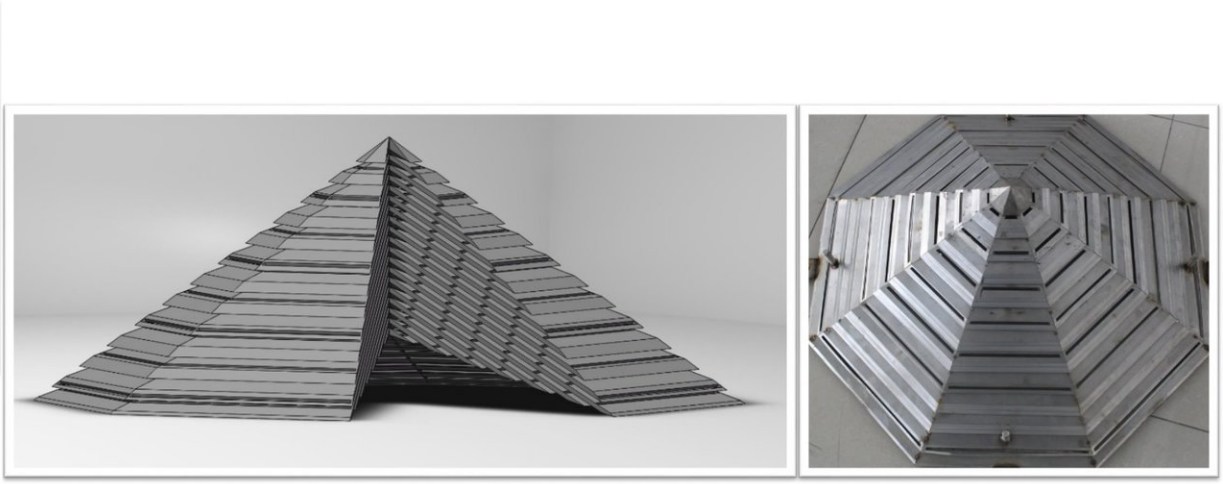


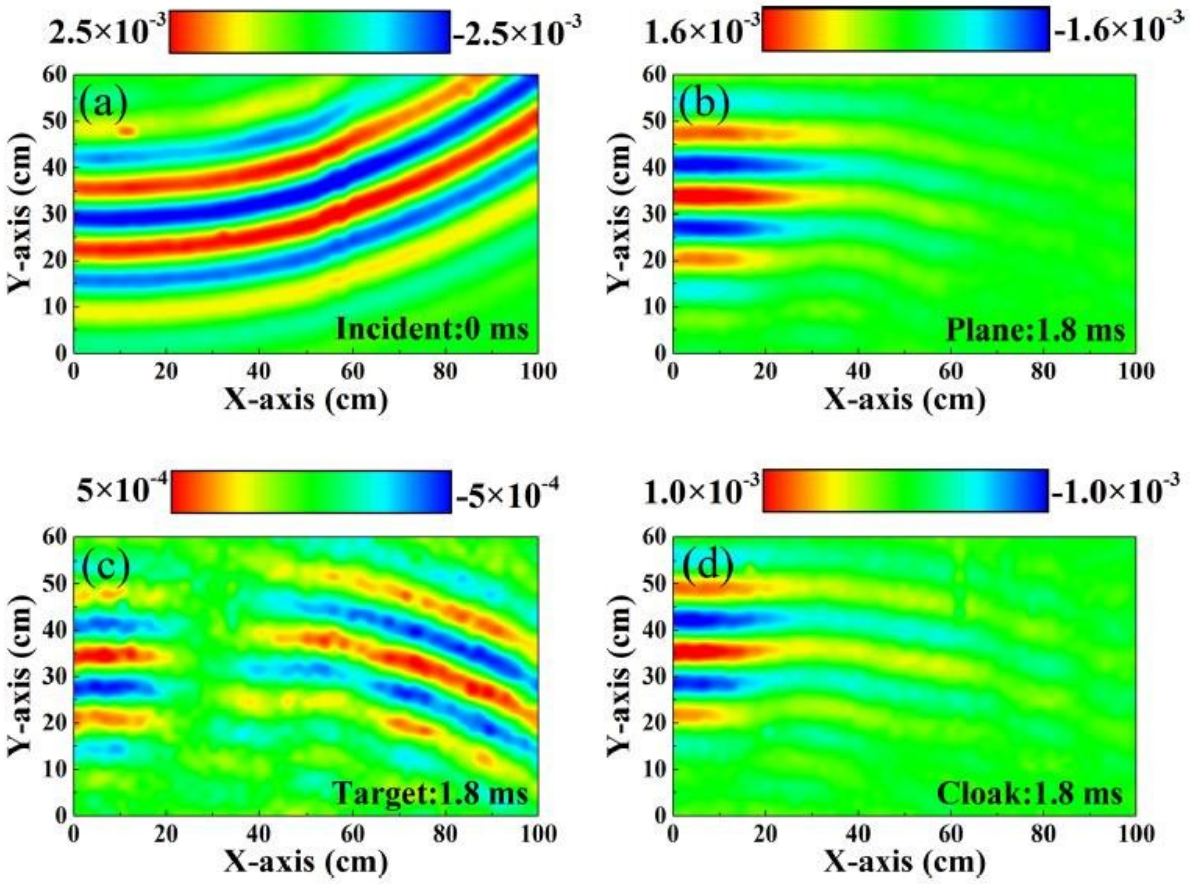
Model and photograph of the 3D underwater acoustic carpet cloak composed of over 700 steel strips. Credit: IOA

Cloaking is one of the most eye-catching technologies in sci-fi movies. In two 2018 Marvel films, *Black Panther* and *Avengers: Infinity War*, the fiction country Wakanda, a technologically advanced African nation, is shielded from the outside world using the metal vibranium.

However, in the real world, if you want to hide something, you need to deceive not only the eyes, but also the ears, especially in the underwater environment. Recently, a research team led by Prof. YANG Jun from the Institute of Acoustics (IOA) of the Chinese Academy of Sciences designed and fabricated a 3-D underwater acoustic carpet cloak (UACC) using transformation acoustics. The research was published online in *Applied Physics Letters* on June 1.

Like a shield, the carpet cloak is a material shell that can reflect waves as if they were reflecting off a planar surface. Hence, the cloaked target becomes undetectable to underwater detection instruments like sonar. Using transformation acoustics, the research team first finished the 2-D underwater acoustic carpet cloak with metamaterial last year (*Scientific Reports*, April 6, 2017). However, this structure works only in two dimensions, and becomes immediately detectable when a third dimension is introduced.

To solve this problem, YANG Jun and his IOA team combined transformation acoustics with a reasonable scaling factor, worked out the parameters, and redesigned the unit cell of the 2-D cloak. They designed the 3-D underwater acoustic carpet cloak and then proposed a fabrication and assembly method to manufacture it. The 3-D cloak can hide an object from top to bottom and deal with complex situations, such as acoustic detection in all directions.



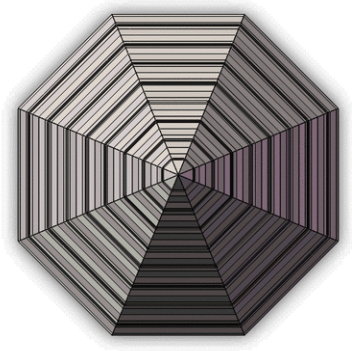
Measured acoustic pressure fields. (a) The incident pressure field at 0 ms. (b)â€€(d) The scattered pressure fields at 1.8 ms from the soft plane (b), the soft target (c), and the cloaked soft target (d), respectively. Credit: IOA

The 3-D underwater acoustic carpet cloak is a pyramid comprising eight triangular pyramids; each triangular pyramid is composed of 92 steel strips using a rectangle lattice, similar to a wafer biscuit. More vividly,by removing the core from a big solid pyramid, it is possible to hide something safely in the hollow space remaining.

"To make a 3-D underwater acoustic carpet cloak, researchers needed to construct the structure with 2-D period, survey the influence of the unit

cell's resonance, examine the camouflage effect at the ridge of the sample, and other problems. In addition, the fabrication and assembly of the 3-D device required more elaborate design. The extension of the UACC from 2-D to 3-D represents important progress in applied physics," said YANG.

In experimental tests, a short Gaussian pulse propagated towards the target covered with the carpet cloak, and the waves backscattered toward their origin. The cloaked object successfully mimicked the reflecting surface and was undetectable by sound detection technology. Meanwhile, the measured acoustic pressure fields from the vertical view demonstrated the effectiveness of the designed 3-D structure in every direction.



The 3D UACC looks like a shield from the vertical view, and a pyramid from the side view. Credit: IOA

"As the next step, we will try to make the 3-D underwater acoustic carpet cloak smaller and lighter," said YANG.

More information: Yafeng Bi et al, Experimental demonstration of

three-dimensional broadband underwater acoustic carpet cloak, *Applied Physics Letters* (2018). DOI: 10.1063/1.5026199

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