Studying spinning-induced scattering of sound to create next-generation acoustic devices using new phonon modes

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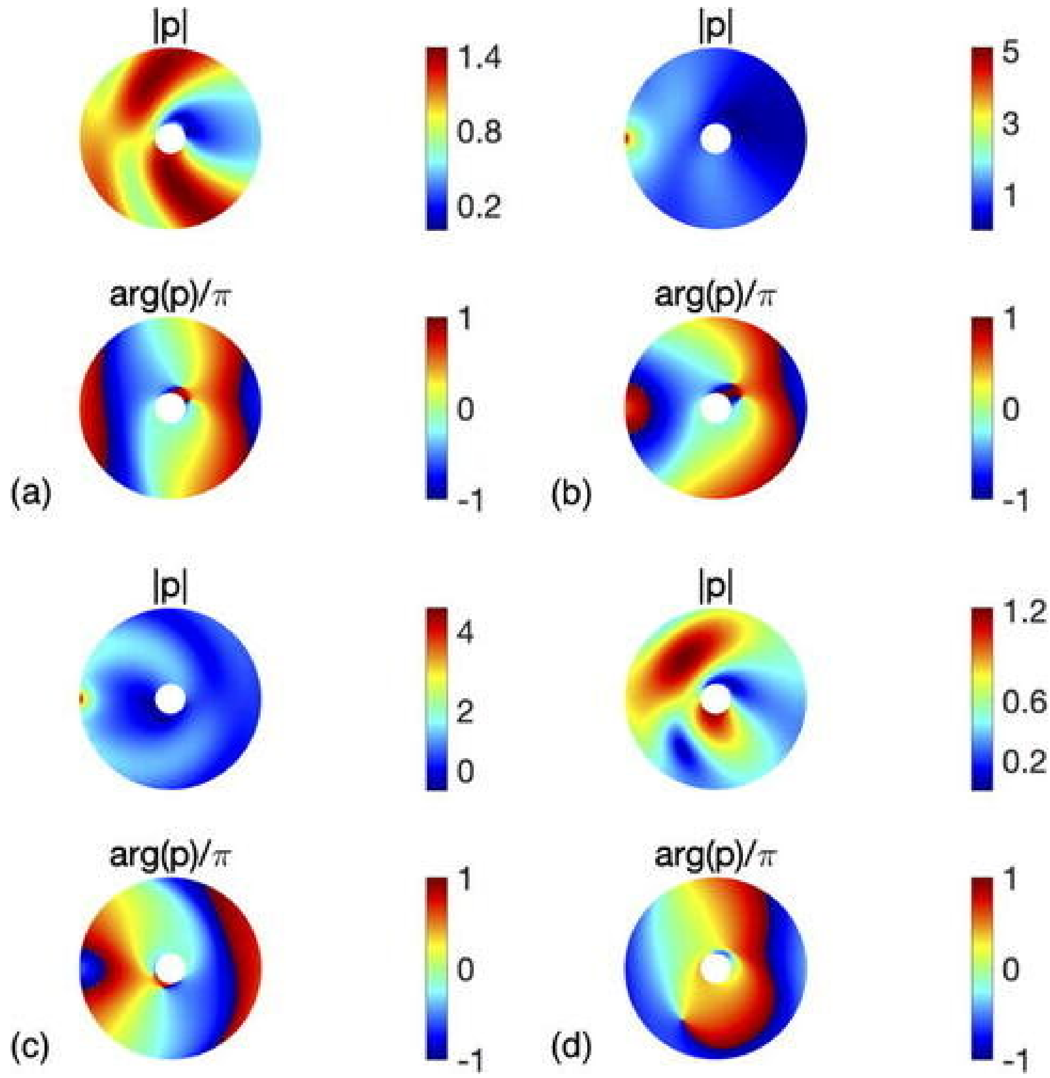

|p| and arg(p)/π of total pressure in the presence of a spinning cylinder with radius a = 0.35 m (white disks) and $\rho = 1000\ kg/m^3$ and $1/\beta = 2.22$ GPa, for

different incident signals: (a) a plane wave with a frequency of 170 Hz, (b) a converging, (c) a diverging cylindrical beam located at r_0=6 m from the origin of the coordinates, and (d) a quasi-Gaussian beam of order l = 1. The spinning frequency of the cylinder is 300 Hz. Credit: *Applied Physics Letters* (2022). DOI: 10.1063/5.0097041

Interactions between a spinning object and soundwaves could help develop high-precision tools, such as tweezers that control the motion and position of submillimeter objects by manipulating acoustic waves, a KAUST-led international team suggests.

Acoustic metamaterials, which can be tailored to transmit, trap and amplify sound waves at specific frequencies, are expected to enable innovative technologies in fields ranging from precision sensing to surgical tools. Extensive research has produced a range of metamaterials, such as ultrasonic lenses that focus 60 kilohertz soundwaves underwater to improve imaging and devices that could shield objects from sonar. However, these have focused on wave phenomena involving static objects. Therefore, the effects of motion on soundwaves remain lightly explored.

"Motion provides more degrees of freedom and features that do not exist in still systems," says research scientist Mohamed Farhat. For example, the Doppler effect occurs when the relative motion of a wave source and its observer changes the perceived frequency of a wave, such as the siren of an ambulance moving past a bystander.

Now, Farhat, Wu and coworkers have investigated the interaction of acoustic beams with a cylindrical object rotating around its vertical axis and evaluated the scattering radiation torque and force resulting from this interaction.

The researchers had previously discovered that scattering solely induced by the simple rotation of cylindrical objects gave rise to unexpected properties and made those objects invisible to sonar detection. This prompted them to use the unusual interaction of an acoustic beam with a similar spinning object to generate radiation torque and force, Farhat says.

The nature of the incident beams affected the scattering induced by the spinning object. The resulting radiation torque and force also showed unique and potentially useful features. A single beam striking the spinning cylinder produced a negative radiation force, which suggests that a simple configuration involving a single beam is sufficient to build acoustic tweezers.

The negative force, which is the key ingredient for acoustic tweezers, Farhat says, helps attract ultrasmall objects and enable precise manipulation. Therefore, it becomes possible to consider manipulating objects in opaque and complicated media that are inaccessible to optical tweezers, such as soft biological tissues, using relevant acoustic forces, he adds.

"We are now looking into experimentally validating our findings," Farhat says. The researchers are also evaluating additional uses of spinning fluids, such as nonreciprocal waveguiding and acoustic equivalents of the optical fiber to bring acoustic telecommunications one step closer to practical applications.

More information: Mohamed Farhat et al, Scattering properties of acoustic beams off spinning objects: Induced radiation force and torque, *Applied Physics Letters* (2022). DOI: 10.1063/5.0097041