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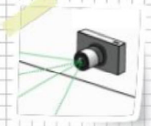
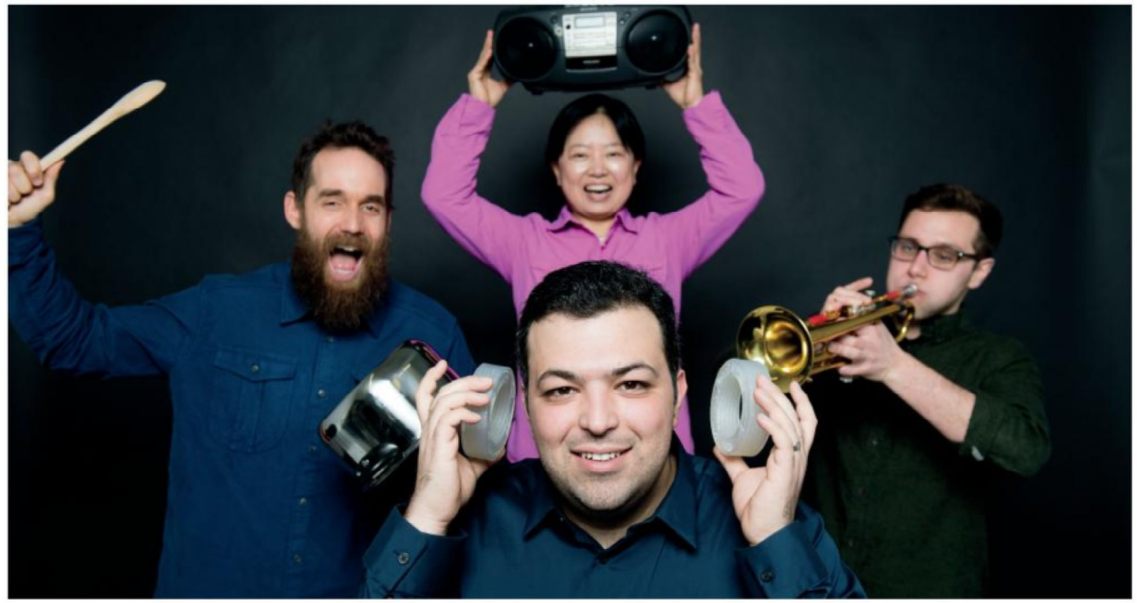


SEEING AROUND CORNERS 5

BLUE LED WATER PURIFIER WINS STUDENT COMPETITION 9



PHOTOGRAPH BY CYDNEY SCOTT

Making the World a Lot Quieter

ENGINEERS HAVE DEVELOPED AN ACOUSTIC METAMATERIAL THAT CAN CANCEL 94 PERCENT OF SOUND

Boston University mechanical and material engineers have created synthetic, sound-silencing structures—acoustic metamaterials—that can block 94 percent of sound. Reza Ghaffarivardavagh (ENG) (front center) holds two of the open, ringlike structures over his ears while Professor Stephan Anderson (MED) (left), Professor Xin Zhang (ENG) (rear center) and Jacob Nikolajczyk (ENG) (right) make a racket.

With the ever-increasing din of drone propellers, airplane turbines, MRI machines, and urban noise pollution blaring in the mind's ear, sound-proofing, or blocking, materials that also allow airflow are becoming increasingly desirable. Although noise-mitigating barricades, called sound baffles, can help drown out loud sounds, they are clunky and not well suited to situations where airflow is also critical.

In a paper published in *Physical Review*, **Professor Xin Zhang** (ME, ECE, BME, MSE) and doctoral fellow Reza Ghaffarivardavagh (ME) outline how, using 3D printing and sophisticated mathematics, it's possible to silence noise using an open, ringlike structure created to mathematically perfect specifications for cutting out sounds while maintaining airflow.

According to Zhang and Ghaffarivardavagh, Boston life is so noisy that you have to find a way to create quiet moments; that's what got them dreaming up a sound baffle that wasn't a barrier at all, but an open conduit. Such a feat could only be possible by developing a material with unusual and unnatural properties (known as a metamaterial), in this case with the ability to exert an isolated influence on sounds—an acoustic metamaterial.

"Sound is made by very tiny disturbances in the air. So, our goal is to silence those tiny vibrations," Zhang explains. "If we want the inside of a structure to be open air, then we have to keep in mind that this will be the pathway through which sound travels."

They calculated the dimensions and specifications that the metamaterial would need in order to interfere with the transmitted sound waves, preventing sound—but not air—from being radiated through the open structure. The basic premise is that the metamaterial needs to be shaped in such a way that it sends incoming sounds back to where they came from.

As a test case, they decided to create a structure that could silence sound from a loudspeaker. Based on their calculations, they modeled the physical dimensions that would most effectively silence noises. Bringing those models to life, they used 3D printing to materialize an open, noise-canceling structure made of plastic. →

CONTINUED

Making the World a Lot Quieter

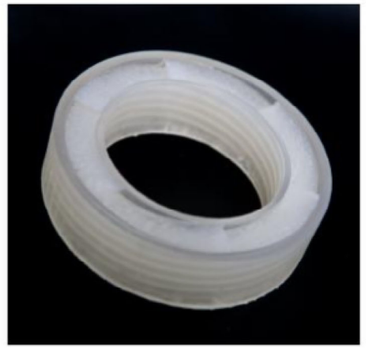
Trying it out in the lab, the researchers sealed the loudspeaker into one end of a PVC pipe. On the other end, the tailor-made acoustic metamaterial was fastened into the opening. With the hit of the play button, the experimental loudspeaker set-up came quietly to life in the lab. Someone standing in the room, based on sense of hearing alone, would never know that the loudspeaker was blasting an irritatingly high-pitched note; however, by peering into the PVC pipe, they would see the loudspeaker's subwoofers thrumming away.

Ringing around the internal perimeter of the pipe's mouth, the metamaterial works like a mute button until the moment Ghaffarivardavagh reaches down and pulls it free, when the lab suddenly echoes with the screeching of the loudspeaker's tune.

By comparing sound levels with and without the metamaterial fastened in place, the team found that they could silence nearly all—94 percent—of the noise, making the sounds emanating from the loudspeaker imperceptible to the human ear.

Now that their prototype has proved so effective, the researchers have some big ideas about how their acoustic-silencing metamaterial could go to work making the real world quieter. It could be used to silence drones, which are becoming more prevalent, and also to block the sound of fans and HVAC systems in homes and offices, while still allowing hot or cold air to be circulated unencumbered throughout a building.

Ghaffarivardavagh and Zhang also cite the unsightliness of the sound barriers used today to reduce noise pollution from traffic and see room for an aesthetic upgrade. "Our structure is super lightweight, open and beautiful. Each piece could be used as a tile or brick to scale up and build a sound-canceling, permeable wall," Ghaffarivardavagh points out. **—KAT J. MCALPINE**



The mathematically designed, 3D-printed acoustic metamaterial is shaped in such a way that it sends incoming sounds back to where they came from. Inside the outer ring, a helical pattern interferes with sounds, blocking them from transmitting through the open center while preserving air's ability to flow through.

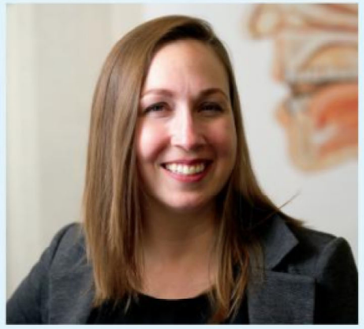
ENG, Smith College Form Innovative Partnership

Together, the College of Engineering and Smith College are pioneering an innovative 4+1 BS-MS partnership program that will offer Smith College Bachelor of Science engineering students enriching research experiences as they prepare to enroll in one of BU's Master of Science engineering programs.

"This partnership with Smith College is a natural extension of our mission to create the Societal Engineer," Dean Kenneth R. Lutchen says. "Much like our students, these talented undergraduates share a commitment to using their engineering skills to address societal challenges, including climate change, health, resource limitations and conflict, among many others."

"Having demonstrated that commitment in their undergraduate careers, Smith College students are well prepared to elevate their impact on society with an advanced engineering degree that includes exciting and impactful research experiences."

Director of Smith's Picker Engineering Program Andrew Guswa says, "With its commitment to creating the Societal Engineer, the College of Engineering at Boston University is a natural partner for the Picker Engineering Program. Smith graduates will apply their integrative engineering background to innovative research and graduate work to address society's challenges. This collaboration allows our undergraduates to experience at BU 14 exciting areas of study, including electrical engineering, materials science, product design, and biomedical engineering—the professional home of **Associate Professor Cara Stepp** (Sargent, BME), one of the first graduates from the Picker Engineering Program."



Associate Professor Cara Stepp

"As an alumna of Smith, I am very excited about this formal partnership, one I wish had existed when I was a student," Stepp adds. "Both the Smith and BU engineering programs aim to prepare students to address societal challenges through the creative application of science and technology. I am convinced that this collaboration is the ideal mechanism to provide cutting-edge research opportunities and graduate study to Smith engineering students."

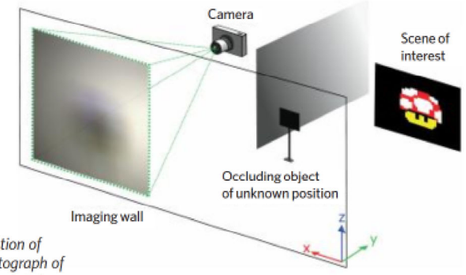
The unique partnership will pair Smith engineering students with faculty in the summer after junior year and give them the opportunity to pursue a follow-on research experience the following summer, just prior to beginning graduate studies. Once enrolled in any of the college's MS programs, they will also have the option of pursuing a thesis supervised by a faculty member.

Smith students will enjoy other benefits in addition to the early application opportunity. BU will allow them to waive the required GRE scores as part of their applications, and early decisions will be rendered as applications arrive. Every accepted Smith student will receive a partial scholarship toward tuition—as well as a stipend and housing supplement for each summer research fellowship—and will have the option of applying to the PhD program of their choice at BU during their initial master's year. **—MICHAEL SEELE**

PHOTOGRAPHS BY CYDNEY SCOTT

Seeing Around Corners

A NEW ALGORITHM EXTRACTS ENOUGH INFORMATION FROM A DULL SHADOW TO RE-CREATE A HIDDEN SCENE



A representation of how the photograph of the penumbra is taken.

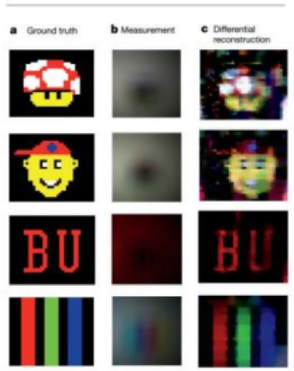
Seeing through walls or around corners has long been considered an unrealistic, superhuman power like mind reading and invisibility. Learning what is in a room without directly looking into it is a goal and area of research called non-line-of-sight vision; until now, the only techniques used to do it haven't been easily translatable to the field. **Associate Professor Vivek Goyal** (ECE) and his team have developed a method of seeing around corners that uses just a simple digital camera and their custom-built algorithms. Their work has been published in *Nature*.

"Non-line-of-sight optical imaging techniques like this one could be very useful for search and rescue teams, emergency response and autonomous vehicles," Goyal says. "If these techniques can be reasonably easy to deploy, then they could be carried around by first responders."

Goyal's research has focused on using very small amounts of information, like a weak light signal, to extract much more information than seems possible. In this paper, Goyal, postdoctoral fellow John Murray-Bruce (ECE) and doctoral student Charles Saunders (ECE) built a way to extract a full-color 2D picture of a scene from a photograph of indistinct shadows, known as a penumbra, on a neighboring wall.

Currently, their technique works only when an object of known shape is blocking the scene in question, but it requires fewer situational necessities compared to other methods.

Murray-Bruce and Saunders say that before this one, most techniques (called "time-of-flight" methods) used lasers to shine light onto a visible surface in the hidden area, then used the light that's reflected back from the lasers to reconstruct an image of that area. And although the groundwork has been laid to use these types of techniques to re-create a color image, it hasn't been done yet. Researchers would need color lasers and to shine each color separately, collect that information, and then reconstruct the image.



Reconstructed images (right) of hidden scenes (left) extracted from penumbra photographs (center).

Another non-line-of-sight technique does not involve lasers but requires the occluding object to move within the scene. This new method does not require calibration, controlled lighting, time-of-flight detection or scene motion and takes under a second to snap the image—or multiple images—and about 20 minutes to re-create the scene in full color.

"Weak signals buried in a lot of noise are important and useful," Goyal stresses. "There is a universality to shadows that can be exploited to extract a lot of important information, even in low-light scenarios."

Although researchers have to know the shape of the occluding object to re-create the scene, they don't need to know where the object is; they can learn that information while also re-creating the scene. And if there is motion within the scene while the photos of the penumbra are being snapped, they can re-create an even more accurate picture.

Goyal believes that his group's and time-of-flight methods complement each other, and future research will examine how to combine both sets of principles to further advance non-line-of-sight vision. ■

A New Way to Count

ULTRA-SENSITIVE MOLECULAR TEST GIVES A MORE ACCURATE MEASUREMENT

When doctors want to know how much of something is in your blood, they use various lab techniques, all of which are designed specifically a particular substance and, although sensitive, take the measurement at the end of the test and capture only the resulting snapshot. Now, with a new method developed by **Professor M. Selim Ünlü**'s (ECE, MSE, BME) lab, researchers can determine a much more exact measurement by continually observing molecular reactions throughout the test. Their work has been published in *Proceedings of the National Academy of Sciences*.

ELISA (enzyme-linked immunosorbent assay) and PCR (polymerase chain reaction) are two common molecular analysis tests. The former uses antibodies to test for proteins; the latter synthetic DNA to test for genetic material. They're commonly used to test for infections and transmittable diseases and show promise in early cancer and traumatic brain injury diagnosis.

In the past decade, advances in these tests have created ways to detect and count very low levels of a target called ultra-sensitive assays. Despite being able to detect single molecules, the readout isn't an exact count, but rather a close estimation.

With each test, scientists have designed specific detection molecules that bind to their target. By then measuring the number of bound targets, they can determine the amount of the target in the blood. But sometimes non-target molecules will also bind, which can result in an inaccurate count. This makes it difficult to test for certain classes of →

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