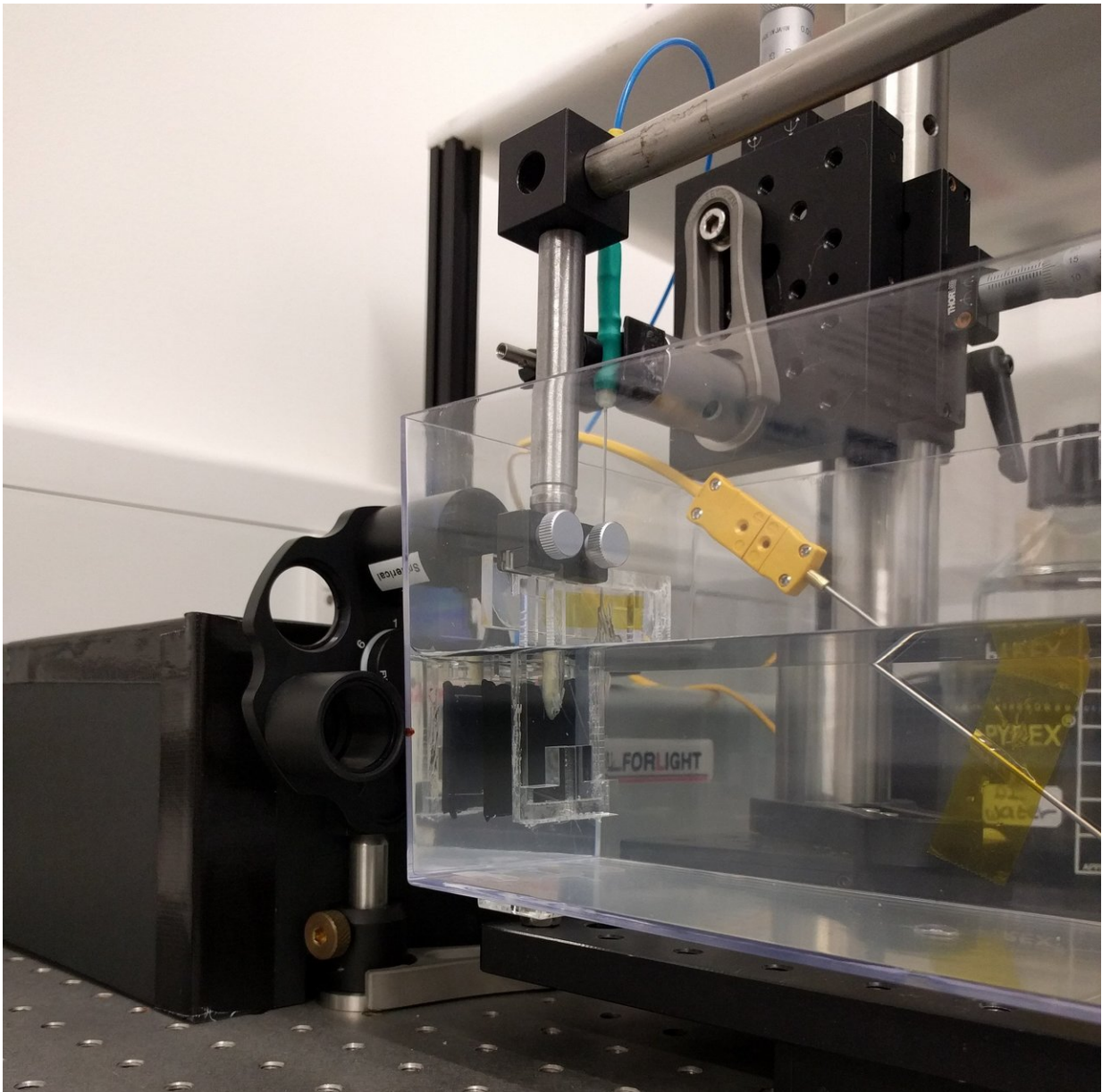


Versatile ultrasound system could transform how doctors use medical imaging

July 2 2018



This prototype is the first all-optical ultrasound imager to demonstrate video-rate, real-time 2D imaging of biological tissue. The achievement is an important step toward making all-optical ultrasound practical for routine clinical use, where it could offer significant advantages over current imaging technology. Credit: Erwin J. Alles, University College London

While ultrasound is one of the most common medical imaging tools, conventional electronic ultrasound devices tend to be bulky and cannot be used at the same time as some other imaging technologies. A new ultrasound system that uses optical, instead of electronic components, could improve performance while giving doctors significantly more flexibility in how they use ultrasound to diagnose and treat medical problems.

In The Optical Society (OSA) journal *Biomedical Optics Express*, researchers demonstrate for the first time the use of an all-optical [ultrasound](#) imager for video-rate, real-time 2-D imaging of biological tissue. The achievement is an important step toward making all-optical ultrasound practical for routine clinical use.

Because they require no electronic components in the imaging [probe](#), all-optical ultrasound systems could be safely used at the same time as magnetic resonance imaging (MRI) scanners. This would give doctors a more comprehensive picture of the tissues around an area of interest, such as a tumor or blood vessel.

"All-optical ultrasound imaging probes have the potential to revolutionize image-guided interventions," said Erwin J. Alles, University College London, United Kingdom. "A lack of electronics and the resulting MRI compatibility will allow for true multimodality image guidance, with probes that are potentially just a fraction of the cost of

conventional electronic counterparts."

Lightbeam scanning mirrors built into the device increase image quality and make it possible to acquire images in different modes. In a clinical setting, this would allow doctors to rapidly toggle between modes on a single instrument to suit the task at hand. Acquiring different types of images using conventional ultrasound systems typically requires separate specialized probes.

"The flexibility offered by the scanning mirrors will allow for seamless switching between 2-D and 3-D imaging, as well as a dynamically adjustable trade-off between image resolution and penetration depth, without the need to swap imaging probe," said Alles. "Especially in a minimally invasive interventional setting, swapping imaging probes is highly disruptive, extends procedure times and introduces risks to the patient."

Eliminating electronics

Conventional ultrasound imagers use arrays of electronic transducers to transmit high-frequency sound waves into tissue and receive the reflections. A computer then constructs images of the tissue.

By contrast, all-optical ultrasound imagers use light to both transmit and receive ultrasound waves. Pulsed laser light is used to generate ultrasound waves, and scanning mirrors control where the waves are transmitted into the tissue. A fiber optic sensor receives the reflected waves.

The electronic components of conventional ultrasound devices make them difficult to miniaturize for internal use, so most existing ultrasound devices are large, handheld probes that are placed against the skin. While some high-resolution minimally invasive ultrasound probes have been

developed, they are too expensive for routine clinical use. Optical components are easily miniaturized and tiny all-optical ultrasound probes would likely be significantly less expensive to manufacture than compact electronic ultrasound systems, researchers say.

Speeding up image processing

To generate images, an all-optical ultrasound system must acquire data from multiple optical source locations, combine them together and then create a visualization that reconstructs the area being imaged.

Researchers have previously demonstrated using all-optical ultrasound to generate high-quality 2-D and 3-D images, but acquiring the images took hours, making these devices too slow to be used in a clinical setting. The new demonstration is the first to acquire and display images with all-optical ultrasound at video rates.

"Through the combination of a new imaging paradigm, new optical ultrasound generating materials, optimized ultrasound source geometries and a highly sensitive fiber-optic ultrasound detector, we achieved image frame rates that were up to three orders of magnitude faster than the current state-of-the-art," said Alles.

A medical multitool

Optical ultrasound systems are inherently more versatile than their electronic counterparts because they can produce sound at a much larger bandwidth. Alles and colleagues demonstrated how the light source can be manipulated to generate either low frequency ultrasound, which results in greater penetration into the tissue, or high frequency ultrasound, which offers higher resolution [images](#) at a shallower depth.

The team tested their prototype system by imaging a deceased zebrafish, as well as a pig artery that they manipulated to emulate the dynamics of pulsing blood. The demonstration showed imaging capabilities comparable to an electronic high-frequency ultrasound system, with a sustained frame rate of 15 Hertz, a dynamic range of 30 decibels, a penetration depth of 6 millimeters and a resolution of 75 by 100 micrometers.

To adapt the technology for clinical use, the researchers are working to develop a long, flexible imaging probe for free-hand operation, as well as miniaturized versions for endoscopic applications.

More information: Erwin J. Alles et al, Video-rate all-optical ultrasound imaging, *Biomedical Optics Express* (2018). [DOI: 10.1364/BOE.9.003481](https://doi.org/10.1364/BOE.9.003481)

Provided by Optical Society of America

Citation: Versatile ultrasound system could transform how doctors use medical imaging (2018, July 2) retrieved 17 April 2024 from <https://phys.org/news/2018-07-versatile-ultrasound-doctors-medical-imaging.html>

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