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IMAGING

Photoacoustics in a snap

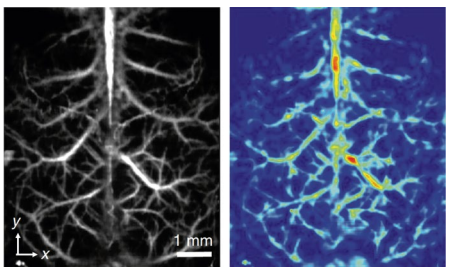
Photoacoustic topography through an ergodic relay increases imaging throughput and opens a path toward wearable devices.

Photoacoustic imaging, also called optoacoustic imaging, takes advantage of the absorptive properties of materials and is especially useful for imaging blood. A photoacoustic signal is generated by illuminating a tissue of interest. Some molecules within the tissue absorb the light and release energy in the form of ultrasonic acoustic waves, which can then be measured and converted into an image. The generated signals can be detected either point by point with a single ultrasonic transducer or in parallel using transducer arrays. In the latter case, more transducers allow the capture of more energy, which improves the signal-to-noise ratio.

To circumvent the need for transducer arrays with their associated size and cost, Lihong Wang from the California Institute of Technology in Pasadena and his team came up with an alternative strategy. "Can we use one transducer to function as many transducers?" Wang asked. The solution to this problem was inspired by work in the ultrasound field and involved an ergodic relay in the detection path. The researchers called this approach photoacoustic topography through an ergodic relay, or PATER.

In standard photoacoustic tomography using transducer arrays, the acoustic wave plane is directly detected in the elements of the transducer array. In PATER, the acoustic wave plane goes through an ergodic relay cavity before reaching a single-element detector. The ergodic relay modifies or scrambles acoustic pulses depending on their origin. Wang explains that in an ergodic relay a short acoustic pulse will be stretched into a very broad pulse.

"We are using the scrambling of ultrasound waves within the ergodic relay to generate unique signatures for each detection point on the input surface. And with calibration later on we can decode it," explains Wang. "Every point will have a unique stretched pulse. [Upon] widefield illumination, then we get a linear combination of all those stretched pulses," he says, and these pulses can then be unmixed. Hence, "after initial calibration of the ergodic relay a transducer can function as many transducers for snapshot imaging," he says, and points out that the underlying physics is actually quite straightforward.



Images of the mouse vasculature acquired for calibration of PATER (left) and acquired with PATER (right). Reproduced with permission from Li, Y. et al. *Nat. Photonics* https://doi.org/10.1038/s41566-019-0576-2 (2020).

Nevertheless, it took several years and the expertise of several students to get the approach working. "It's not a single person's job," says Wang.

The researchers demonstrated the capabilities of the PATER system by imaging hemodynamic activity in the mouse brain in response to paw stimulations. They could also track circulating melanoma cells in the mouse vasculature by the strong absorption of melanin in these cells.

The PATER system does have some drawbacks. "We are losing some signal because the [ergodic relay] cavity doesn't couple 100%," acknowledges Wang. He and his team are looking into ways to improve the transmission efficiency. "Whether that's a fundamental limitation, we have to wait and see," says Wang. Conversely, a major advantage of the PATER system over array-based systems is the reduced cost and smaller size. Wang envisions using this approach in wearable devices, which could be useful in clinical applications but also in basic research. With some optimization, it should be possible to miniaturize the PATER system for imaging of hemodynamic activity in rodents.

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