Many medical imaging techniques that use light suffer from a fundamental challenge of not being able to "see" deep inside the body. Light is highly scattering inside the body, limiting how deep we can "see" to around 2 cm. An easy way to understand this is by holding up a flashlight to your fingertips. Light clearly passes through, leaving behind a warm red hue, yet you cannot see any visual indication of the bone in your finger.

To overcome this imaging problem, many other techniques or "modalities" of imaging have been invented that exploit other properties of the body to create an image. A few examples of this are ultrasound, magnetic resonance imaging (MRI), positron emission tomography (PET), and computed tomography (CT). However, these techniques themselves have drawbacks of being expensive, unsuitable for repeated use, or providing limited contrast for certain tissue types.

To tackle this challenge, a newtechniquecalledultrasoundopticaltomography(UOT) was developed to combinethebestofbothworlds, the rich contrast that light provides and the penetration depth ultrasound can reach. In UOT, pulses of light and ultrasound are sent into the body simultaneously. The ultrasound shifts the "colour" or frequency of the light by a tiny amount in the region where the two overlap, effectively "tagging" the light and marking exactly where it has been. Using a special material called photorefractive crystal, the tagged light is filtered out and used to reconstruct an image from deep inside the body. Currently, UOT builds images one point at a time by focusing the ultrasound to a single spot and tracking its propagation. This is slow and produces only a small amount of tagged light.

This work explores a new approach, that instead of using a focused ultrasound pulse, the ultrasound is sent into the tissue in a structured pattern that is able to cover a much larger area at once. The image is then reconstructed with the help of a mathematical tool called the Fourier transform. Fourier transforms are used everywhere in our lives and even in other medical imaging techniques like MRI and CT scan. A simple way to understand what the Fourier transform does is the following: imagine you have a model made out of LEGO bricks that you want to recreate. You could examine the model one brick at a time, which would take a lot of time. Or you could ask a better question, how many 3 × 3 blue pieces exist in the model, or how many 3 × 4 green ones there are? TheFourier transform works similarly, it helps you extract global patterns. In terms of UOT, this means more tagged light and possibly faster image formation. Ultimately, the goal of this work is to bring UOT closer to real clinical use, particularly for the detection and diagnosis of breast cancer, and hopefully in the future, monitoring of oxygen level in the heart