New Technique Makes Tissues Transparent

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If humans had see-through skin like a jellyfish, spotting disease like cancer would be a snap: Just look, and see a tumor form or grow.

But humans, of course, are not remotely diaphanous. "The reason a person is not transparent is that their tissues are highly scattering," sending light waves careening through the tissue instead of straight through, as they would through the tissue of that jellyfish, explains Changhuei Yang of the California Institute of Technology.

This scattering, in addition to rendering all of us opaque, makes the detection of disease a much trickier issue, requiring a host of diagnostic tests and procedures. But not, perhaps, for much longer, thanks to a new optical trick developed by Yang, an assistant professor of electrical engineering and bioengineering, and his colleagues, that counteracts the scattering of light and removes the distortion it creates in images.

A study describing the process appears in the February issue of the journal *Nature Photonics*.

It is well known that light scattering in a material is not exactly the random and unpredictable process one might imagine. In fact, scattering is deterministic, which means that the path that a beam of light takes as it traverses a particular slice of tissue and bounces and rebounds off of individual cells, is entirely predictable; if you again bounce light through that same swath of cells, it will scatter in exactly the same way.

The process is even reversible; if the individual photons of light that scattered through the tissue could be collected and sent back through the tissue, they'd bounce back along the same path and converge at the original spot from which they were sent. "The process is similar to the scattering of billiard balls on a pool table. If you can precisely reverse the paths and velocities of the billiard balls, you can cause the billiard balls to reassemble themselves into a rack," Yang explains.

Yang, along with his colleagues at Caltech, École Polytechnique Fédérale de Lausanne in Switzerland, and MIT, exploited this phenomenon to offset the murky nature of our tissues.

Their technique, called turbidity suppression by optical phase conjugation (TSOPC), is surprisingly simple. The scientists used a holographic crystal to record the scattered light pattern emerging from a 0.46-mm-thick piece of chicken breast. They then holographically played the pattern back through the tissue section to recover the original light beam. "This is similar to grabbing hold of the direction of time flow and turning it around; the time-reversed photons must retrace their trajectories through the tissue," Yang says. "The task is formidable though, as this is comparable to starting with a rack of 10 to the 18th power billiard balls (or photons), scattering them around the table, and attempting to reassemble them into a rack."

"Until we did this study, it wasn't clear that the effect will be observable with biological tissues. We were pleasantly surprised that the effect was readily observable and remarkably robust," Yang says. "This study opens up numerous possibilities in the use of optical time reversal in biomedicine."

One possible use of the technique is in photodynamic therapy, in which a highly focused beam of light is aimed at cancerous cells that have absorbed cell-killing light-sensitive compounds. When the light hits the cells, the compounds are activated and destroy the cells. Photodynamic therapy is most effective in treating cancers on the skin surface. Yang's technique, however, offers a way to concentrate light onto cancer-killing compounds located more deeply within tissue.

Yang's idea is to inject strongly light-scattering particles that are coated with light-activated cancer-killing drugs into diseased tissue. Shine a beam of light into the tissue, and it would be reflected off the scattering compounds as it bounces through the tissue. Some of the scattered light would return to the source, where it could be recorded as a hologram.

This hologram would contain information about the path that the scattered light took through the tissue, and, in effect, describe the optimal path BACK toward the light-scattering molecule--and the cancer-killing compounds. Playing back the signal with a stronger burst of light will then activate the therapeutic drugs, which kill the cancer cells.

In addition, the technique could offer a way to power miniature implants buried deep within tissues. "If you take a quick survey of what is out there at present, you will see that implants are fairly large," Yang says. "For example, a pacemaker is about the size of a cell phone. Why are they so big? A large part of the reason is because they need to carry their own power sources."

The key to making smaller implants, then--say, the size of a pen tip--is to eliminate the power sources. "I think implants that carry photovoltaic receivers are particularly promising," he says. "The effect can be applied to tailor light-delivery mechanisms to efficiently channel light into tissues and onto these implants."

Source: Caltech