New growth for optical coherence tomography

Optical coherence tomography is an emerging medical imaging technology with an ever growing list of applications. **Marie Freebody** speaks to James Fujimoto to find out more.

James Fujimoto is a professor at the Massachusetts Institute of Technology in the US and is one of the key players responsible for the invention and development of optical coherence tomography (OCT) in the early 1990s. Fujimoto also has an active commercial side and has co-founded two companies, one of which was acquired by Zeiss and led to the first OCT instrument for clinical ophthalmology. The second company is currently developing intravascular and endoscopic OCT.

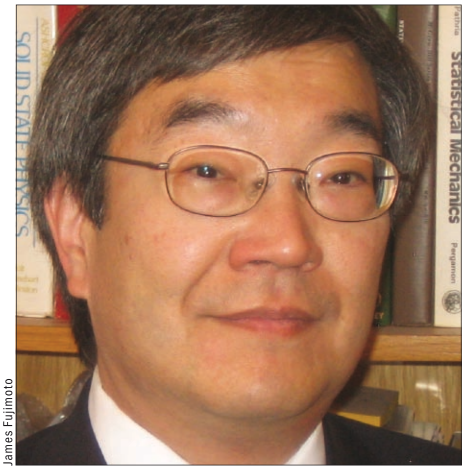
Can you explain how OCT works?

OCT enables micron-scale, cross-sectional and three-dimensional (3D) imaging of biological tissues *in situ* and in real time. The technique measures the echo time delay and intensity of backscattered light using interferometry with broadband light sources or with frequency swept lasers. The approach is analogous to ultrasound, except that imaging is performed by measuring light rather than sound. The imaging depths are typically around 2 mm, which is shallow compared with ultrasound. However, OCT can provide much higher image resolutions of a few microns.

Two-dimensional (2D), cross-sectional OCT images of tissue are constructed by scanning the optical beam and performing axial measurements of light echoes at different transverse positions. The result is a 2D array, which represents the backscattering in a cross-sectional slice of the tissue. 3D imaging can also be performed by using a 2D scan pattern.

Why is it important to develop OCT?

OCT can function as a type of "optical biopsy", imaging tissue microstructure *in situ* and in real time without removing and processing tissue specimens. OCT can be used where excisional biopsy would be hazardous or impossible, such as imaging the retina, coronary arteries or nervous tissues. There is considerable interest in developing OCT to guide excisional biopsy, to reduce false negatives and improve imaging sensitivity. Since OCT can see beneath the surface of tissue, it can also be used to guide surgical interventional procedures. OCT also has the advantage that it can perform repeated imaging over a period of time and therefore monitor the progression of disease or response to therapy.



James Fujimoto

Technology translator: James Fujimoto from MIT.

What are the main applications and when do you expect them to occur?

OCT has had the largest impact in ophthalmology where it can be used to create cross-sectional images of retinal pathology with higher resolution than any other non-invasive imaging technique. In addition, image information can be quantitatively analyzed to measure specific features, such as retinal thickness or nerve fibre layer thickness, which are indicators of diabetic retinopathy or glaucoma.

OCT is also being developed for intravascular imaging, where it shows promise for assessing unstable plaque in coronary arteries and guiding interventional procedures, such as stent placement.

Additional applications include guiding biopsy for cancer detection and guiding surgical procedures. OCT is also having a powerful impact in fundamental research in areas ranging from small animal imaging, which is important for pharmaceutical discovery and development, to non-destructive evaluation of materials.

What would you say is the most important recent advance?

One of the most powerful recent advances in OCT is the development of "Fourier domain" detection methods. Conventional OCT technology used scanning low coherence interferometers and measured echoes of light sequentially as a function of time. In contrast, Fourier domain detection measures the spectrum of the interference using a broadband light source and a high-speed spectrometer, or a swept laser light source and detectors. Information on the echo time delay of light is obtained by Fourier transforming the interference spectrum.

The new technique enables imaging to be performed between 50 and 500 times faster than previously possible. This is a powerful advance because the extremely high speeds enable 3D imaging to be performed *in vivo*. 3D-OCT provides comprehensive volumetric information on structure and promises to dramatically enhance visualization and diagnostic performance.

What are the key challenges left to overcome in this field?

Perhaps the most challenging issue is to translate the technology from the laboratory to the clinic. The clinical environment is completely different from the research environment in the university and requires a team of investigators who understand and work effectively in both environments. This type of research and development is extremely complex, but advances can have a significant impact on healthcare and represent an important contribution to society.

What do you think the next big breakthrough will be?

It is tempting to think about scientific advances in terms of breakthroughs, but I don't believe that this is necessarily the case. Most of the time advances are made by individual research groups performing dedicated work on a series of highly specific problems or applications. A series of evolutionary advances, taken together, can create a major, revolutionary advance.