From Individual Cells To Entire Bodies, Lasers Shine

Duke University

DURHAM, N.C. – From a single cell to a whole organism, the laser will play an increasingly important role in diagnosing and treating disease.

So says a Duke University bioengineer who is using the latest applications of a technology invented 50 years ago to peer into the genetic material of cells, to detect the earliest signs of disease in a single cell, and to non-invasively and optically biopsy tissue inside the body for the tell-tale traces of cancer.

“Laser technology is definitely bringing a bright future to biomedical research and clinical applications, as it is capable of yielding the critical information bridging molecular structure and physiological function, which is the most important process in the understanding, treatment and prevention of disease,” said Tuan Vo-Dinh, an invited speaker at the annual meeting of the American Association for the Advancement of Science being held in Washington, D.C.

Vo-Dinh is the R. Eugene and Susie E. Goodson Distinguished Professor of Biomedical Engineering, Professor of Chemistry, and Director of The Fitzpatrick Institute for Photonics

“Lasers could ultimately lead to the development of new tools for early diagnostics, drug discovery, and medical treatment beyond the cellular level to that of individual organelles and even DNA, the building block of life,” he said.

Vo-Dinh and his colleagues have developed what they call “molecular sentinels,” which are basically metallic nanoparticles attached to snippets of DNA that can detect early signs of disease at the DNA and RNA level, leading to effective treatment. When light is directed at samples from the cell, the nanoparticle can “report” back about the conditions inside. This optical technique is known as surface-enhanced Raman scattering (SERS), which Vo-Dinh has pioneered its practical application over the past 20 years.

When laser light is directed at a sample, the target molecule vibrates and scatters back its own unique light, often referred to as the Raman scatter. However, this Raman response is extremely weak. When the target molecule is coupled with a metal nanoparticle, the Raman response is greatly enhanced by the SERS effect -- often by more than a million times, Vo-Dinh said.

“This technology can be used to directly detect chemical species and biological species with exquisite sensitivity or to monitor inside single cells,” Vo-Dinh said. “In other terms, the nanoprobes play the role of molecular sentinels patrolling the sample solution by switching their warning light on and off when significant event occurs.”

Using this approach, researchers have already been able to “read” the gene sequences of infectious agents like HIV and early biomarkers of other diseases, such as the breast cancer genes known as BRCA1 and ERB2 breast cancer genes.

Also in the field of biosensing, researchers have developed optical nanosensors, which when excited by laser light, can probe physiological parameters such pH levels, individual biochemical markers such as cancer-causing agent metabolites attached to DNA, and monitor molecular pathways such as apoptosis, or programmed cell death.

“These nanosensors are leading to a new generation of tools that can detect the earliest signs of disease at the single-cell level in a systems biology approach and have the potential to drastically change our fundamental understanding of the life process itself,” Vo-Dinh said.

Duke bioengineers have already developed methods for using light, including lasers, for performing biopsies without actually having to remove any tissue from patients. Known as laser induced fluorescence, physicians can spot precancerous or cancerous cells by simply shining light from the fiber tip inserted into an endoscope, for example, during a routine endoscopy procedure in the gastro-intestinal tract.

“We are also studying the use of laser induced fluorescence to detect other types of cancer as well, such as that of the skin and brain,” Vo-Dinh said. “These optical biopsy technologies could revolutionize medical diagnostics since the measurements are performed in a matter of seconds and no tissue needs to be removed.”#

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