New insights into how lasers cut flesh

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Prof. Shane Hutson working in his laboratory. Credit: Daniel Dubois

Lasers are at the cutting edge of surgery. From cosmetic to brain surgery, intense beams of coherent light are gradually replacing the steel scalpel for many procedures.

Despite this increasing popularity, there is still a lot that scientists do not know about the ways in which laser light interacts with living tissue. Now, some of these basic questions have been answered in the first investigation of how ultraviolet lasers – similar to those used in LASIK eye surgery – cut living tissues. It was published online in *Physical Review Letters* on October 10.

The effect that powerful lasers have on actual flesh varies both with the wavelength, or color, of the light and the duration of the pulses that they produce. The specific wavelengths of light that are absorbed by, reflected from or pass through different types of tissue can vary substantially. Therefore, different types of lasers work best in different medical procedures.

For lasers with pulse lengths of a millionth of a second or less, there are two basic cutting regimes:

-- Mid-infrared lasers with long wavelengths cut by burning. That is, they heat up the tissue to the point where the chemical bonds holding it together break down. Because they automatically cauterize the cuts that they make, infrared lasers are used frequently for surgery in areas where there is a lot of bleeding.

-- Shorter wavelength lasers in the near-infrared, visible and ultraviolet range cut by an entirely different mechanism. They create a series of micro-explosions that break the molecules apart. During each laser pulse, high-intensity light at the laser focus creates an electrically-charged gas known as a plasma. At the end of each laser pulse, the plasma collapses and the energy released produces the micro-explosions. As a result, these lasers – particularly the ultraviolet ones – can cut more precisely and produce less collateral damage than mid-infrared lasers. That is why they are being used for eye surgery, delicate brain surgery and microsurgery.

“This is the first study that looks at the plasma dynamics of ultraviolet lasers in living tissue,” says Shane Hutson, assistant professor of physics at Vanderbilt University who conducted the research with post-doctoral student Xiaoyan Ma. “The subject has been extensively studied in water and, because biological systems are overwhelmingly water by weight, you would expect it to behave in the same fashion. However, we found a surprising number of differences.”

One such difference involves the elasticity, or stretchiness, of tissue. By stretching and absorbing energy, the biological matrix constrains the growth of the micro-explosions. As a result, the explosions tend to be considerably smaller than they are in water. This reduces the damage that the laser beam causes while cutting flesh. This effect had been predicted, but the researchers found that it is considerably larger than expected.

Another surprising difference involves the origination of the individual plasma “bubbles.” All it takes to seed such a bubble is a few free electrons. These electrons pick up energy from the laser beam and start a cascade process that produces a bubble that grows until it contains millions of quadrillions of free electrons. Subsequent collapse of this plasma bubble causes a micro-explosion. In pure water, it is very difficult to get those first few electrons. Water molecules have to absorb several light photons at once before they will release any electrons. So a high-powered beam is required.

“But in a biological system there is a ubiquitous molecule, called NADH, that cells use to donate and absorb electrons. It turns out that this molecule absorbs photons at near ultraviolet wavelengths. So it produces seed electrons when exposed to ultraviolet laser light at very low intensities,” says Hutson. This means that in tissue containing significant amounts of NADH, ultraviolet lasers don’t need as much power to cut effectively as people have thought.

The cornea in the eye is an example of tissue that has very little NADH. As a result, it responds to an ultraviolet laser beam more like water than skin or other kinds of tissue, according to the researcher.

“Now that we have a better sense of how tissue properties affect the laser ablation process, we can do a better job of predicting how the laser will work with new types of tissue,” says Hutson.

Source: Vanderbilt University