FIBER LASERS

2 µm thulium fiber laser offers precision surgery promise

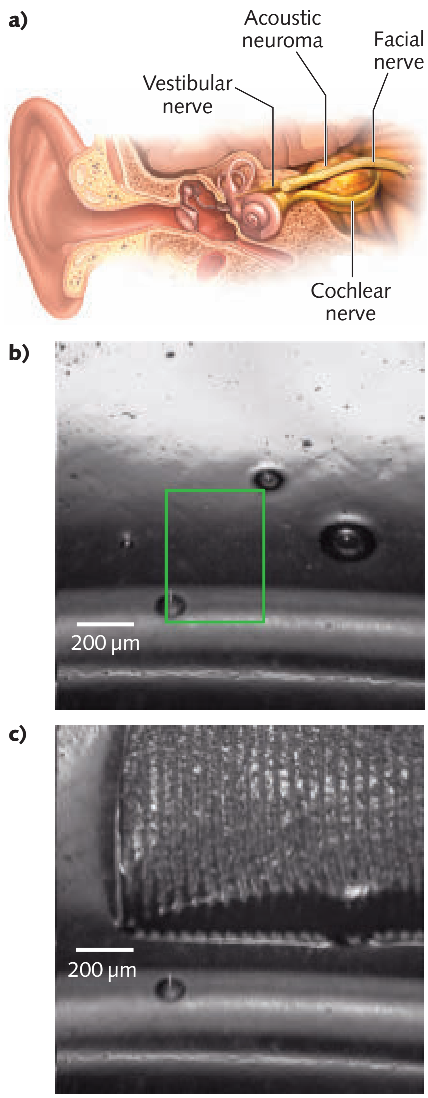
Thulium (Tm^{3+})-doped fiber lasers are of increasing interest for life science applications for two key reasons: first, their near-infrared (near-IR) output at 1940 nm falls within the broad 1900 nm absorption band of liquid water, enabling a host of biological tissue-related medical applications; and second, practical advances in Tm^{3+} fiber laser power and reliability are making them a cost-effective choice for laser-system builders. Together, these developments have motivated a new study to investigate the potential of Tm^{3+} fiber lasers for precision surgical applications—particularly for neurologic cancers such as acoustic neuroma.

In a collaborative effort involving Coherent (Santa Clara, CA) scientists and engineers who have developed and optimized a custom Tm^{3+} laser, and the research team of professor Thomas Milner in the Biomedical Engineering Department at the University of Texas, Austin, surgical application of thulium-based lasers is approaching viability.[1]

Milner explains, "For some time, we have been interested in achieving better outcomes in precision (micro) surgical procedures, with the particular example of neurologic cancer. This is highly challenging because neurologic cancers are typically located in confined spaces due to protective bony structures, and damage to surrounding blood vessels produces bleeding which obscures the surgeon's vision. We're focused on developed diagnostic tools such as tomographic imaging that enhance visualization of these tumors, and surgical systems that can precisely cut and remove tumor cells and tissues without damage to adjacent normal neurologic structures."

Surgical applications

In one example, Milner describes how thulium lasers could benefit patients with a type of cancer found in the inner ear called acoustic neuroma (see figure). As an acoustic neuroma enlarges, it puts pressure on the facial and cochlear



As a typical acoustic neuroma enlarges, it puts pressure on both the facial and cochlear nerves, making it a challenge to surgically remove the neuroma using traditional cutting tools without damaging these nerves (a; *courtesy of The Mayo Institute)*. In another potential surgical application for a thulium laser, a blood vessel embedded in a tissue phantom (b) is shown after laser passes were made over the tissue (c), whereby the vessel was spared. *(Courtesy of the University of Texas, Austin/Milner group)* nerves, resulting in severe pain and facial deformity. "Due to limited imaging capabilities combined with rough cutting and nonspecific cautery tools, a conventional surgical approach to acoustic neuroma can result in a damaged nerve and a distorted facial appearance," Milner says.

For several critical reasons, Milner's team has identified a *Q*-switched Tm^{3+} laser as an ideal tool in this application. First, efficient absorption of the laser wavelength by soft tissues (which are full of water) leads to highly localized ablation at high removal rates, together with minimized peripheral tissue damage. This is further enhanced by using short *Q*-switched pulses with high peak power. In addition, the near-IR wavelength can be fiber-delivered, enabling use at inaccessible body locations as well as supporting many laparoscopic surgical applications.

The Milner team and Coherent (formerly Nufern) engineers worked together to define target laser parameters for this application. "While it is challenging to efficiently obtain stable, high-power output from thulium-doped fiber lasers, we achieved success through optimized Tm^{3+} doping in the fiber, resonant pumping at 793 nm, the use of fiber with a pedestal cross-section, optimization of the oscillator fiber length, and optimized splice recipes," says Coherent components and defense sales manager Jeff Wojtkiewicz. "This resulted in a laser with a 120 ns pulse width, >15 W average power, and >4 kW peak power—parameters believed to be a good match for these types of microsurgery applications."

Milner's group used this custom laser to investigate precision ablation of tissue phantoms made with 70% water and 30% gelatin mix. Specifically, the tissue phantoms contained 500-μm-diameter cylindrical polymer conduits embedded into the gel to mimic blood vessels in tissues. Preliminary results showed that they could indeed ablate the gel without damage to these conduits, solving the non-laser surgical problem wherein bleeding impairs tissue visibility during surgery.

Another common surgical application of cutting close to, but sparing, sensitive tissue structures (such as nerves) was also explored. For this study, a vessel was embedded deeper in the tissue phantom. Again, the laser was able to cut precisely and cleanly close to the vessel with minimal thermal damage.

"The applications for fiber lasers are still growing rapidly," Wojtkiewicz says. "We believe that our ability to develop custom gain and passive fibers at new wavelengths should broaden this market even further, and enable many other medical, industrial, and scientific applications in the future."—*Gail Overton*

REFERENCE

1. P. Ahmadi et al., "1940 nm all-fiber Q-switched fiber laser," *Proc. SPIE*, 10083, 100830G (Feb. 22, 2017).