Taking laser nerve stimulation from the lab to the hospital

Lasers are very good at precisely targeting specific human cells and then quickly heating them to the point of cooking or even exploding them. But the team of engineers and physicians at Vanderbilt University wanted to find a way to stimulate nerve cells without destroying them.

“What we wanted to do is gently tickle the nerve cells, not fry them,” explains team member Duco Jansen.

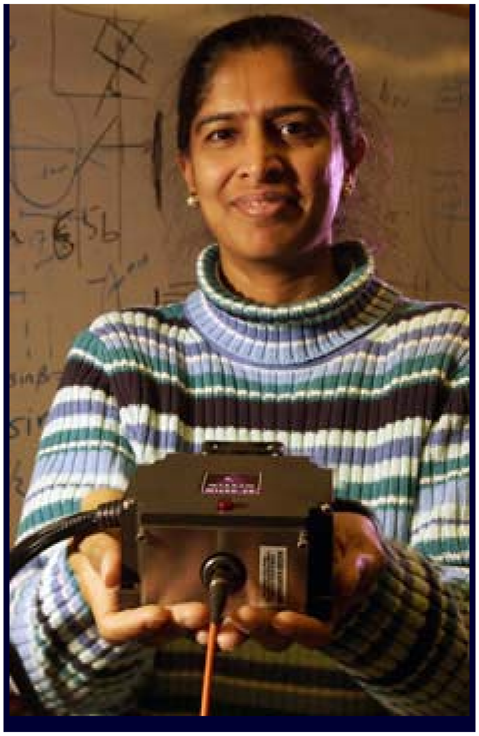

Photo by Daniel Dubois

Anita Mahadevan-Jansen holds the prototype of a commercial laser nerve stimulator that is being developed with the Aculight Corporation.

He knew it was possible because he had actually witnessed it a few times during laser surgeries. “I have seen accidental nerve stimulation during heart surgery,” he says. “If the wrong area is targeted with the laser, you can accidentally cause fibrillation. So we knew that a laser could stimulate nerve cell activity.”

The first question they had to answer was, “What wavelength and power of laser light is the best at turning nerves on?” Lasers come in a wide variety of wavelengths, intensities and other critical properties. Since no one had used lasers to stimulate nerve cells before, no one knew what sort of laser technology would do the job.

Their search for the perfect wavelength began at the Vanderbilt W.W. Keck Foundation Free-Electron Laser (FEL). Most conventional lasers only produce light at a single, fixed color or wavelength. The basement-sized FEL, one of only a few free-electron research lasers in the world, has the ability to produce laser light in a wide range of infrared wavelengths (two to nine microns), and power levels, peaking at more than 10 megawatts.

In Jansen’s more than ten years of working with the FEL, he has concentrated on determining the specific laser wavelengths that can cut different types of tissue effectively while doing minimal harm to surrounding cells. To stimulate nerve cells, however, the researchers needed to use light that nerve cells could absorb well enough to stimulate without producing enough heat to damage them.

“We tuned the FEL to several wavelengths that we had computationally determined might be good candidates before we found some that worked well,” Jansen says.

The FEL experiments were carried out using laboratory rats. After several weeks of experimenting to determine the effects of different laser frequency on the rats’ nerve cells, Jansen and his associates discovered two wavelengths that were particularly effective in stimulating nerve cells without damaging the tissue.

The next step was to develop a transportable laser that can do the job.

As it turned out, one of those wavelengths was within the capability of a Holmium:YAG laser already sitting on a table in Jansen’s lab. The Holmium:YAG laser produces laser light by exciting Holmium atoms sprinkled, or “doped,” within a crystal made of yttrium, aluminum, and garnet. The laser generates laser light with a wavelength of 2,120 nanometers, which is in infrared part of the spectrum and so is invisible to humans.

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Experiments on rats using the Holmium:YAG laser proved that it worked just as well as the FEL. But to make the technology truly accessible in clinical applications in doctors' offices and hospitals, the equipment needed to be smaller and easier to use than the Holmium:YAG.

"Ideally we wanted to be able to use a diode laser, because they are small, low-intensity and require relatively little power," Jansen says. Diode lasers generate laser light by passing electrons through a semiconductor device that produces coherent radiation (all waves are the same frequency and phase). They are ubiquitous, found in CD players, laser printers, remote-control devices and laser pointers.

Jansen was just beginning to search for a vendor to work with him to develop a diode laser capable of producing the desired wavelength when he ran into a scientist from Aculight Corporation at an optics convention.

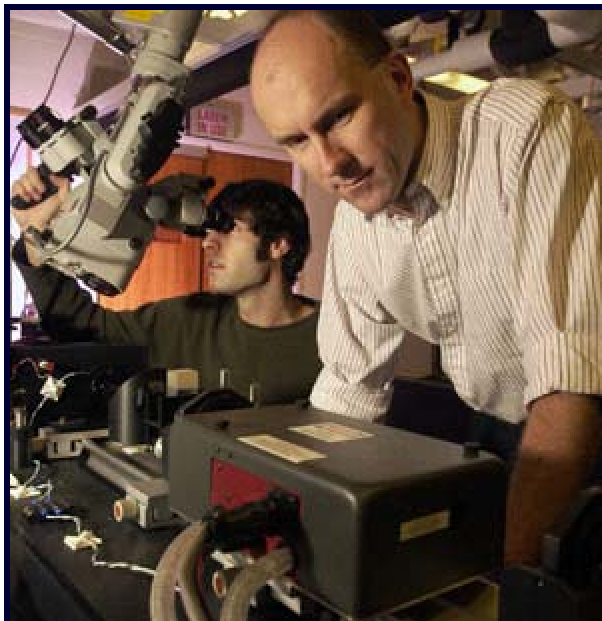

Photo by Daniel Dubois

Jonathan Wells, a doctoral student in Biomedical Engineering, and Duco Jansen are working with the desktop-sized Holmium YAG laser that produces one of the infrared wavelengths that is effective at neural stimulation. Although much smaller than the free-electron laser, the Homium: YAG provided valuable data about optical nerve stimulation, but is still too large and expensive to allow widespread use of the technique.

The Aculight engineer was intrigued with Jansen's research, and they were both surprised to find that the company was already working on a laser with similar capabilities to those that Jansen needed. The company, which is based in Bothell, WA, produces advanced laser systems mostly for U.S. defense applications and had recently decided to broaden its market base into the biomedical field.

"It is quite remarkable that the technology developed to protect aircraft from incoming missiles can be directly adapted for this kind of medical application" Jansen says.

The idea of producing a new medical device that could help patients struggling with a variety of illnesses through nerve stimulation was exciting to company officials, and their engineers went to work to adapt their equipment to meet Jansen's specifications.

The company has produced a prototype, and Jansen and other Vanderbilt engineers are working with them to test the equipment on laboratory rats and fine-tune it to the precision required for human trials. Then the equipment will be tested during rhyzotomy, a procedure whereby a neurosurgeon clips a section of nerve which is causing spastic motions somewhere in the body. During the experiment, the laser will be fired on the nerve cell to be eliminated, the amount of electrical charge it then produces will be recorded, and then the surgeon will remove the nerve. The excised nerve will be analyzed to see if the laser has damaged it in any way.

"This data will give us feedback on how well the equipment works to stimulate human nerve cells without harming them," Jansen says.

Jansen hopes that the equipment will be in use for surgery to locate specific peripheral nerves, such as in carpal tunnel syndrome surgery, by spring of 2005.

-- V.C.C