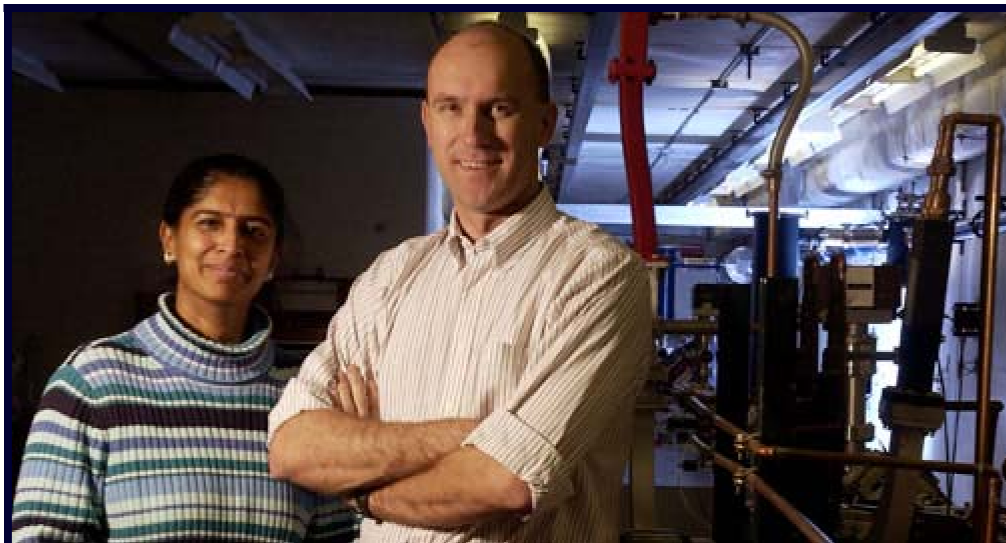

Photo by Daniel Dubois

Anita and Duco Jansen with the free-electron laser in the background

Stimulating nerve cells with laser precision

A major step toward controlling artificial limbs directly from the brain

By Vivian Cooper-Capps
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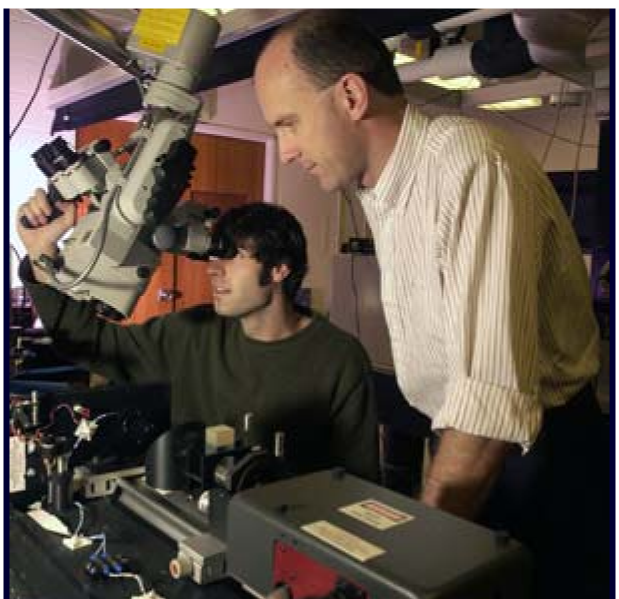


Photo by Daniel Dubois

Jonathan Wells, left, and Duco Jansen using a pulsed infrared laser that was used to help determine the characteristics of the laser light that can stimulate neurons safely and effectively.

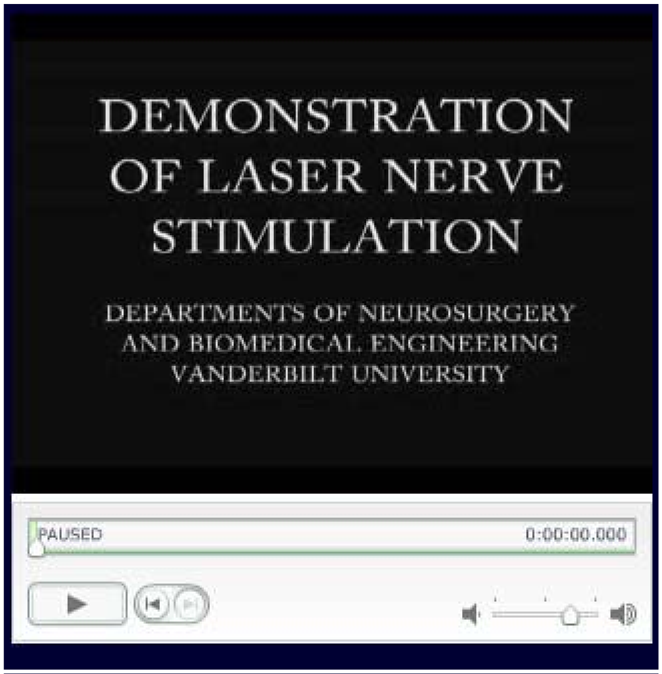
Biomedical engineers and physicians at Vanderbilt University have brought the day when artificial limbs will be controlled directly by the brain considerably closer by discovering a method that uses laser light, rather than electricity, to stimulate and control nerve cells.

The researchers have discovered that low-intensity infrared laser light can spark specific nerves to life, exciting a leg or even individual toes without actually touching the nerve cells.

"This technique brings nerve stimulation out of the Dark Ages," says Vanderbilt Assistant Professor of Biomedical Engineering and Neurological Surgery Anita Mahadevan-Jansen. "Much work is going on around the world trying to make electric nerve stimulation better, but the technique is inherently limited. Using lasers instead, we can simultaneously excite and record the responses of nerve fibers with much greater precision, accuracy and effectiveness."

The method was developed by Mahadevan-Jansen, her husband Duco Jansen, associate professor of biomedical engineering and neurological surgery; along with Peter Konrad and Chris Kao – both assistant professors of neurological surgery – and biomedical engineering doctoral student Jonathon Wells.

In an experiment with rats, the scientists used a laser to stimulate the sciatic nerve and to control muscles in the animal’s hind leg and individual toes, demonstrating accuracy beyond the limitations of electrical stimulation. Immediately following the experiment the rats regained full use of their legs with no signs of weakness or damage.



Video clip that shows a rat’s foot and toe being stimulated with a laser

Konrad, who directs Vanderbilt’s functional neurosurgery program, points out that neurostimulation is ideally done cell by cell. “The problem with the conventional electrical method is that we have a large zone around our target neuron that also is affected, simply because of the way electricity travels throughout the tissue. Using light to stimulate neurons, we can pick off a single neuron without affecting the other neurons around it.”

According to Kao, it should be possible to create a machine in a couple of months hat helps guide neurosurgeons to the target nerves during rhizotomy, a procedure that frees someone from a spastic or seemingly frozen muscle, as when someone's head is stuck in a tortuous position. Currently, once they identify the proper neural region, surgeons pinpoint the individual nerves by a process of elimination, striking nerves with an electric probe while the patient is awake to ensure that the right nerve has been located.

But electrical probes create a halo of electrical activity in surrounding neurons, creating a "blind spot" and other inaccuracies in the recording and analysis procedure, making it tedious and difficult to locate the correct nerve.

The poppy-seed bagel theorem

Photo by Dana Johnson

Pete Konrad during surgery

Optics, on the other hand, can deliver laser precision by stimulating only the nerve cell of interest.

The idea of optical stimulation started as the scientists questioned whether they could accurately detect the movement of an electrical impulse from a nerve cell through the brain. Konrad suggested using light to trace the activity and Mahadevan-Jansen thought of using laser light to stimulate nerves and to actually generate the activity.

Vanderbilt's W.M. Keck Foundation Free Electron Laser Center was the perfect facility to give it a try. The Department of Defense-funded FEL, one of only a handful in the world and the only one equipped to perform medical experimental research, was used to see if the idea worked and to determine the optimal settings for the laser.

Photo by Steve Green

Chris Kao

Now that the research team has shown that the process works and that it is safe, they are turning their attention to studying the exact mechanisms behind the stimulation effects. The most likely candidates, Jansen and Wells say, include a photothermal or mechanical effect, or perhaps a combination of the two.

The scientists are beginning experiments in the central nervous system.

Mahadevan-Jansen says the technique, which is pending patent approval, is not the only novel aspect of this work. "This research results from the marriage of biomedical engineering, optical science and neurological research," she says. "Some programs are working on optics, and some are working on neurological stimulation, but nobody has put them together."

Imagining future applications, Konrad says he can envision an array of fiber optic threads that runs directly from the brain or spinal cord to a prosthetic arm or leg, creating the ultimate man-machine interface.