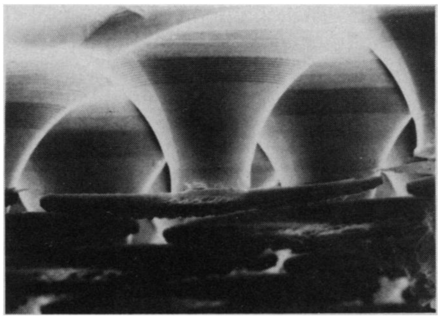
Semiconductor laser is chip off new block

A newly developed microscopic laser offers efficiency, power and other qualities that provide a big advance over conventional microscopic lasers, researchers report. The laser, made of a semiconductor chip, could have wide applications in telecommunications and optical computing, they say.

The laser, built at Sandia National Laboratories in Albuquerque, N.M., shoots a beam from the top surface of a gallium arsenide chip only 10 microns thick. It is the first highly efficient, surface-emitting semiconductor laser successfully developed, says Paul Gourley, who led the research team. Most semiconductor lasers emit light from the thin side of the chip, and the few existing types of top-surface-emitting lasers are not very efficient, he adds.

One of the advantages of large laser beams is that they spread so little as they travel over long distances. But getting such a focused beam out of a microscopic laser has been difficult, Gourley says. The beam produced by the new laser is special because it spreads very little (as little as 2.5°), whereas conventional semiconductor lasers tend to put out fuzzy beams that spread from the mouth of the laser as much as 35°.



A cross section of the laser crystal shows the cone-shaped area where the laser emits. The black lines across the cone are mirror layers, and between lies the "active laser cavity."

Sandia National Laboratories

The new laser's fine focus and circular beam make it perfect for sending light down optical fibers in telecommunications networks, the Sandia team reports. "Conventional semiconductor lasers can only produce an oval beam that wastes a lot of light when coupled to the circular entrance of an optical fiber," Gourley says.

All lasers work by amplifying light as it passes through energized material. Most lasers increase the amplification by bouncing the light back and forth through energized material lying between parallel mirrors, multiplying the number of photons passing through. The new semiconductor laser consists of one solid crystal that has been built layer by layer. Each layer has been modified to form many mirrored surfaces and an energizing region lying between them.

"What's really novel is that this laser is extremely short," Gourley says. The region between the mirrors is about 1 micron long, which is "one-hundredth the length of conventional semiconductor lasers," he says.

The efficiency of the laser is due in part to the characteristics of the mirrors. With high reflectivity, the mirrors make most of the light take multiple trips through the energizing region for maximum amplification. The mirrors also absorb none of the laser light when photons do pass through them, Gourley says.

At this point, the laser has to be "pumped" with photons from another source to get it going, but Gourley thinks that in a year or so his team will generate a laser beam using just an electrical current.

This laser is exactly right for producing the strong laser light needed for an optical computer, Gourley says. It can also serve as a kind of electro-optical switch, allowing one laser to pump a new beam if the current is turned on, and producing nothing if the current is turned off, he adds.

In fact, the crystal growth technology used to make the laser is now being applied to make all the elements of an optical computer, Gourley says. "We have the source of light—the laser—a switch of light, a modulator of light and a detector. You can imagine an integrated system that employs these in an optical computer," he says. *— C. Vaughan*

Endurance superstars may be 'born to run'

A study of muscle chemistry in world-class long-distance runners suggests these athletes' ability to "reach levels of physical endurance unattainable by all but a very few persons" lies largely in their genes, researchers report in the December Proceedings of the National Academy of Sciences (Vol.85, No.23).

Scientists have known that different people have different proportions of endurance, or "slow-twitch," muscle fibers relative to "fast-twitch," short-energy-burst fibers. They have also documented that training can alter the proportion of these two types. They have debated, however, how large a role genes play, says study leader Jane H. Park of Vanderbilt University in Nashville, Tenn.

"I think this is one of the first times people have said that genes are important [in determining human endurance performance]," Park told Science News. One research team had suggested a genetic component when it found an "unexpectedly high" number of slow-twitch fibers in the untrained muscle of certain endurance athletes. However, "there are no earlier measurements of metabolites in untrained muscle of athletes to our knowledge," Park and her colleagues write.

They found that the untrained wrist muscles of the four long-distance runners studied maintained force better during prolonged exercise — involving repeated wrist flexion against a resisting bar—than did those of five healthy but relatively sedentary sex-matched individuals of comparable age. By measuring muscle metabolites—chemicals involved in muscle contraction — the researchers determined that the athletes' muscles sustained their chemical energy reserves much better than did those of the nonathletes. And indicators of muscle acidity showed that the athletes, unlike the controls, did not supplement their energy supplies through anaerobic muscle metabolism, which causes muscle fatigue and lactic acid buildup, according to Park.

Instead of examining muscle composition by surgically removing tiny bits of muscle tissue, Park and her co-workers placed the subjects' arms in the bore of a superconducting magnet and used magnetic resonance spectroscopy to monitor how the phosphorus in various muscle metabolites reacted to the magnet. This noninvasive method enabled them to collect a large quantity of data on a minute-to-minute basis. It also allowed them to examine a larger, and thus more representative, mass of tissue than possible with biopsies, they say.

The researchers found that, both at rest and during exercise, the athletes' untrained wrist muscles maintained higher levels of adenosine triphosphate, which supplies muscles' chemical energy, and phosphocreatine, the "storehouse" of adenosine triphosphate. The athletes "start out with a bigger storehouse [of energy] and maintain a bigger storehouse all the way through the exercise," Park says.

Muscle acidity increased in the nonathletes at the start of exercise, indicating the use of lactic acid-producing anaerobic metabolism, which quickly peters out. Acid buildup caused the nonathletes' performance to decline by tiring their muscles, which had too few slow-twitch fibers to sustain the previous level of force, Park says. No such acid increase occurred in the athletes' muscles.

Although athletic training is known to increase heart and lung capacity, the experimental exercise protocol did not significantly increase participants' pulse and respiratory rates, say the researchers. They note, however, that "additional systemic effects of training cannot be completely excluded." *— I. Wickelgren*