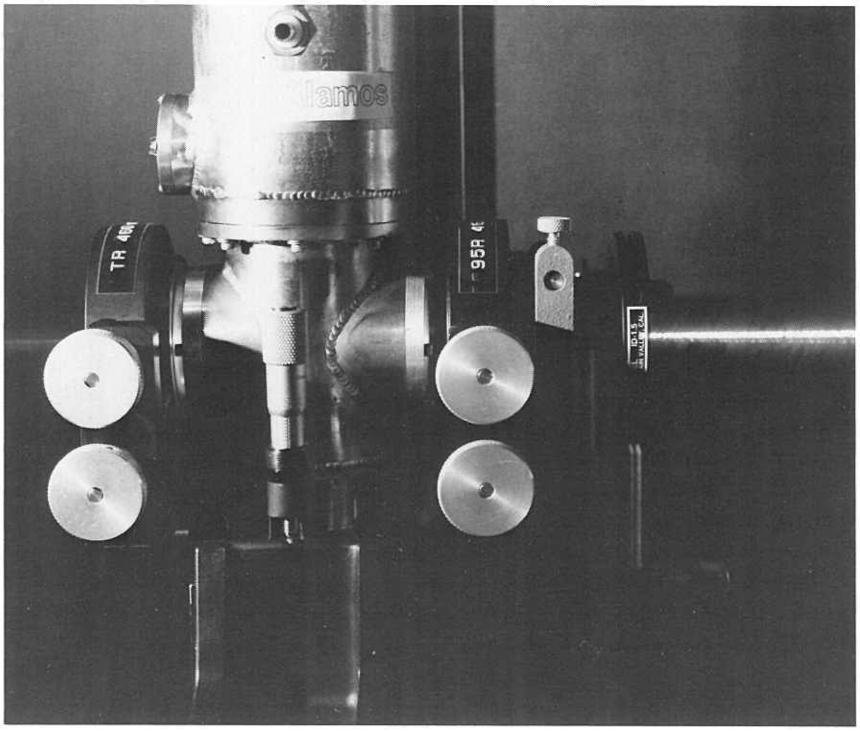
A New Solid-State Laser

Inventors: Dinh C. Nguyen, George E. Faulkner, and Nigel J. Cockroft, Chemical and Laser Sciences Division



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The Upconversion Solid-State Laser is compact, durable, and rugged. It operates in the blue-green region of visible light.

Lasers are devices that produce an intense beam of light of a very pure single color. The light beam is created when atoms or molecules at low energy levels are excited to higher levels, which causes them to give off light and, in the process, return to a lower level of energy. If light of a certain wavelength is made to impinge on an atom while the latter is excited, the atom can be stimulated to emit radiation that is in phase (or in step) with the wave that stimulates it, and the new emission amplifies the passing wave. If the phenomenon can be multiplied sufficiently, the resulting beam may be intense enough to vaporize the hardest and most heat-resistant materials.

The rapidly advancing field of laser technology includes lasers that emit infrared, ultraviolet, and visible light. The Upconversion Solid-State Laser, which was developed at Los Alamos, belongs to the most recent class of solid-state lasers, devices that can generate visible light efficiently and reliably from solid-state materials. In recognition of the significance of this invention, *Research and Development Magazine* granted the inventors a 1990 R&D 100 Award; the awards are given each year for the one hundred most significant technical innovations.

The Invention—Principle of Operation and Advantages

The Upconversion Solid-State Laser is the first laser in its class to operate in the blue-green region of visible light. To emit blue-green light, the new laser converts the less energetic infrared light into the more energetic blue-green light through a process of multiphoton excitation or upconversion. For this process to occur, a source of infrared light is first needed, such as a semiconductor diode laser that converts electrical energy into infrared light. The diode laser is not only extremely efficient and high-powered, but also very small. The infrared radiation produced by the diode laser is pumped into our laser to excite the electrons of an optically active atom—in this case thulium contained in a crystal—to a higher energy level.

Laser pumping is analogous to moving up one step of a ladder. However, the atoms in our laser must move two steps or more up the energy ladder by absorbing infrared photons. Laser pumping more than one step up the energy ladder is a process known as upconversion. It is the atoms high up on the energy ladder that can emit visible light. Our laser does not increase energy; instead, it takes a number of photons of low energy and converts them into fewer photons of high energy. It can therefore emit light that is more energetic than the light used for pumping.

Earlier researchers used bulky, inefficient, and fragile gas or dye lasers to generate blue light. More recently, other researchers have obtained blue-green light from solid-state lasers that require an external color-conversion crystal, which is easily damaged or misaligned. The laser developed at Los Alamos does not involve external conversion processes. It is compact, durable, and rugged.

High efficiency is yet another advantage of the new laser developed at Los Alamos. In comparison with traditional gas lasers, the Upconversion Solid-State Laser is ten times more efficient. It also generates little waste heat and can easily be air cooled.

Applications and Patents

Because the Upconversion Solid-State Laser emits visible light in the blue-green band of the spectrum, it is most suitable for underwater applications. Only beams in that particular region of visible light can

For more information about the Upconversion Solid-State Laser, please contact Dr. Ronald E. Barks, Industrial Applications Office, Los Alamos National Laboratory, P.O. Box 1663, Mail Stop M899, Los Alamos, NM 87545, Telephone (505) 667-3839.

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travel far under water. That is why our laser could become a most important tool in underwater communication from vessel to vessel and from vessel to shore. In the latter application, a solid-state laser in space (on a satellite) would send an encoded beam to a submarine receiver that would detect and decode the message, thus allowing people on the vessel to communicate directly with friendly forces on shore; the submarine would not have to surface.

Our laser is not only ideal for submarine communication or for illuminating underwater objects of interest but also for optical storage. Compact audio and video entertainment discs as well as optical discs for computers will have much greater storage density when manufacturers switch from infrared- to visible-light lasers.

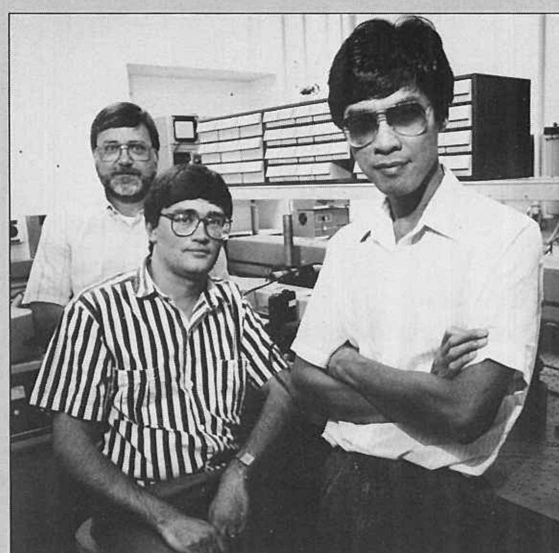
Moreover, the Upconversion Solid-State Laser holds the promise of numerous biomedical applications. Our laser will make locating tumors in the body and performing scar-free tissue welding and retina welding faster and more reliable. Indeed, the potential applications for this laser are almost limitless: chemical analyses, biological cell sorting, photography, photochemistry of biological systems, and even sequencing of the human genome. And finally, because it is compact—small enough to fit on a desktop—the Upconversion Solid-State Laser, along with other new technologies, has the potential of bringing lasers out of the laboratory and turning them into common tools available to all levels of technology.

A patent has been awarded for the Upconversion Solid-State Laser, and the technology is ready for licensing or technology transfer.

INVENTOR Dinh Nguyen is a repeat R&D 100 Award winner. His first award, in 1988, was for collaborating in the development of a photoelectron injector. In 1990, Nguyen received another award for developing the Upconversion Solid-State Laser. Nguyen obtained a B.S. in chemistry in 1979 from Indiana University and a Ph.D. in analytical chemistry in 1984 from the University of Wisconsin. He joined the Chemical and Laser Sciences Division at Los Alamos in 1984 as a postdoctoral fellow and has remained at the Laboratory as a staff member in the same division. So far, he has authored and co-authored more than twenty publications. In recognition of his professional achievements, Nguyen received a Los Alamos National Laboratory Distinguished Performance Award in 1988.

Inventor Nigel Cockroft earned a B.Sc. in physics with honors in 1984 and a Ph.D. in physics in 1987 from the University of Canterbury in Christchurch, New Zealand. After being a postdoctoral fellow in the Department of Chemistry at the University of Wisconsin, Cockroft joined the Chemical and Laser Sciences Division at Los Alamos as a postdoctoral fellow in 1989. His main research interests include studying energy upconversion techniques, developing new types of visible-light lasers pumped by infrared sources, and investigating new photonic devices.

After obtaining a Bachelor of Technology diploma in laser electro-optics technology and an Associate of Applied Science degree in 1974 from Texas State Technical Institute, George Faulkner came to Los Alamos to work as a laser research technician. In 1980, he accepted a position as an engineering development technician with Texas Instruments in Dallas, where he spent eight years. In 1988, Faulkner came back to Los Alamos to work as a laser research technician in the Chemical and Laser Sciences Division. He is interested in software and hardware development of computer data acquisition systems as well as experimental setups and hardware modifications.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Pictured from left are George E. Faulkner, Nigel J. Cockroft, and Dinh C. Nguyen.

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