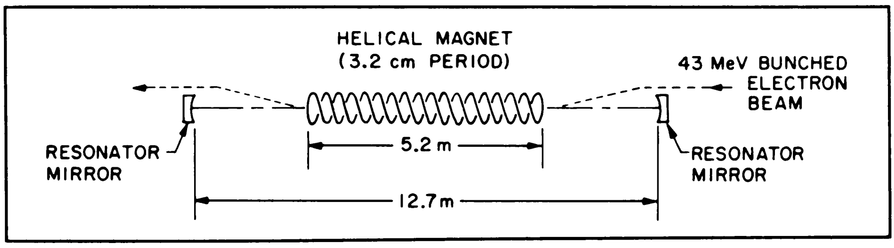
SCIENCE NEWS OF THE WEEK

First Operation of a Free-Electron Laser



Deacon et al./Phys. Rev Letts

Free electrons in a periodic magnetic field produce laser amplification in infrared.

"Ever since the first maser experiment in 1954," a group of physicists from the Stanford University High Energy Physics Laboratory point out, physicists have wished for a maser or laser that was tunable over a wide band of frequencies. Lasers and masers that depend on electrons bound in atoms and molecules are limited to one, or at most, a few, discrete frequencies corresponding to the quantum jumps permitted by the orbital structure of the atom or molecule of the lasing substance. Sometimes harmonics of basic frequencies can be developed, and there are a class of dye lasers that are tunable over short stretches of the spectrum, but pushing them can burn out the dye.

Now the Stanford group reports an important experiment that could lead to a type of laser that, in principle at least, would be tunable over a wide range of the spectrum from infrared through the visible down to the ultraviolet. It uses free electrons as the lasing element. This first operation of a free-electron laser is reported in the April 15 PHYSICAL REVIEW LETTERS by D. A. G. Deacon, L. R. Elias, J. M. J. Madey, G. J. Ramian, H. A. Schwettman and T. I. Smith.

Free electrons are unconstrained by the permitted energy and orbit states of atoms and molecules. If they can be energized and caused to emit coherently, in principle they could emit quanta of any frequency desired. The technique is to take electrons energized by an accelerator and pass them through a spatially periodic magnetic field set up by a coil. The periodic field causes the electrons to corkscrew up and down, and in this state they are likely to produce synchrotron radiation. Passage through the electron beam of a weak beam of radiation of the proper frequency ought to stimulate coherent emissions and laser-style amplification.

The report indicates that this is just what happens. An electron beam of 43 million electron-volts energy from Stanford's superconducting accelerator was passed through a field of 2.4 kilogauss generated by a superconducting magnet coil. The result was coherent emission at a wavelength of 3.417 microns (in the infrared) that exhibited a power gain factor of 100 million over the random unstimulated emission from the electrons.

The mathematical formula that accounts for what happens will apply in principle to any wavelength you like. The wavelength of emission varies with the energy of the electron beam. Since accelerators can give electrons of a very wide range of energies there is, in principle, no wavelength limit.

There is a power gain problem, as Elias points out. The gain falls off at short wavelengths. It depends on the 3/2 power—the square root cubed—of the electron current, so much stronger electron currents are necessary to produce worthwhile power at short wavelengths. Still the paper in PHYSICAL REVIEW LETTERS estimates that currents now available in electron storage rings could provide a reasonable energy gain at wavelengths through the visible part of the spectrum and down to 1,200 angstroms in the ultraviolet. The experimental problem, Elias says, is whether the electron currents can be taken from the storage ring, put through the laser apparatus and returned to the storage ring in a state where they are in phase with the storage ring's operations, and so can be recirculated for repeated passes.

The group intends to start experimenting with storage-ring currents to see if they can make the method work. They intended to use a 250-million-electron-volt storage ring at the University of Wisconsin, and they may build a small one of their own at Stanford.

Meanwhile, they will be working toward an operating tunable laser in the infrared range. Elias points out that this spectral range is particularly useful for laser chemistry work and separation of different isotopes of a given element, especially the separation of explosive from nonexplosive uranium. Elias says there has been interest in the Stanford experiments from people involved in the laser chemistry work at Los Alamos Scientific Laboratory, where uranium separation is one of the important provinces of the work.

Reed Jensen, one of the leaders of the Los Alamos laser-chemistry work, has to be guarded and nonspecific in his comments because of the classified nature of the Los Alamos operations. But he says that "the work of Dr. Madey's group is very welcome." It is an initial experiment, Jensen reminds us, and "we shouldn't forget that a lot of work has been done with other lasers and that these lasers have carried the burden of the work." Still, "We're delighted with what he's done."

Another center of laser chemistry and isotope-separation work is the Lawrence Livermore Laboratory. The leader of that effort, James I. Davis, calls the Stanford results "a promising preliminary experiment." At the moment, he says, it is too early to discuss applications in the context of Livermore's isotope-separation program, "but we look forward to future work. It is a very original, clever idea."

A laser of this sort would probably not be applicable to thermonuclear fusion, Elias says, because it delivers a high average power rather than the short concentrated bursts desired for fusion application, but there are many other applications in precision chemistry and materials science for this kind of laser if a practical one can be developed. ☐

The heaviest (99) space molecule yet

"Somewhere, over the rainbow," Judy Garland used to sing, was a world of wonders. The actual world out over the rainbow, interstellar space, may not contain anything as chemically complex as lemon drops, but the molecules that astronomers are discovering there are getting so big and so organic that the suggestion that life—or the compounds that later became alive—originated there gains more and more plausibility. The longest, heaviest and most organic molecule yet discovered is cyanotriacetylene (HC_7N), reported last week.

The compound was found in a cloud in the constellation Taurus by a group of observers from the Canadian National Research Council's Hertzberg Institute, using the Algonquin Park Radio Observatory near Pembroke, Ontario. The discoverers are L. W. Avery, N. W. Broten, J. M. McLeod and T. Oka. They were collaborating with a group at the University of Sussex in England led by Harry Kroto, who were doing laboratory work on the compound.

This compound, like so many others of interest to molecular astronomers, is too reactive to exist under ordinary conditions on earth, although it can last a long while in interstellar space where its chances of meeting something to react with are slim. Since it is not a staple of