cern the identities of the agent recognized by the *sev* protein and of the cellular protein or proteins phosphorylated as a result of its tyrosine kinase activity. Growth and differentiation signals may be received at the cell membrane, but they almost certainly must be transmitted to the genes in the nucleus to produce their effects. The phosphorylation reaction presumably plays an integral role in that signal transfer.

Unfortunately, however, the researchers who have been studying the tyrosine kinases of the EGF receptor and oncogene proteins have been frustrated for years in their attempts to determine which of the cellular proteins phosphorylated by the kinases are critical to signal transfer to the nucleus.

Pinpointing the critical protein targets of the *sev* tyrosine kinase may be more feasible because the fruit fly is much more amenable to genetic analysis than the mammalian cells usually used for the growth factor and oncogene studies. It might be possible, for example, to identify mutants that do not produce the R7 cell because they lack the target proteins for the tyrosine kinase. However, Bishop, who has been studying the fruit fly equivalent of the *src* oncogene, cautions that such genetic studies will not necessarily be easy. The experience of the past few years has nonetheless shown that the riddles of development are beginning to yield. ■

JEAN L. MARX

A Free Electron Laser in the Visible

Researchers from Stanford and TRW use the high-quality electron beam from a superconducting linear accelerator and a novel energy-doubling scheme to make visible light

Most of the action in free electron laser research has come in the infrared and microwave regions of the electromagnetic spectrum. A joint effort by researchers from Stanford University and TRW to push into the visible paid off in February, when the investigators succeeded in generating green light with a wavelength of 5280 angstroms. The group, which includes H. Alan Schwettman and Todd Smith of Stanford and George Neil, John Edighoffer, and Steven Fornaca of TRW, is only the second to make a visible-wavelength free electron laser and the first to make one with an output power high enough for use in biomedical, materials, and other research.

In this day and age, there is nothing unique about a visible laser. Conventional instruments are commercially available that are tailored to have a specific combination of properties. They emit high-power radiation, are tunable over a range of wavelengths, generate ultrashort pulses of light, and so on. The advantage of the free electron laser is that it cuts a wide swath through the multidimensional "parameter" space whose coordinates are these properties, making it a highly flexible light source. In some cases, it may be unique. Visible wavelengths, for example, are a stepping-stone to the ultraviolet, where versatile commercial lasers are rare.

Two years ago, Congress directed the Strategic Defense Initiative Organization to initiate a program aimed both at developing free electron laser technology and at searching for applications in medical and materials research. The program is separate from the much larger free electron laser effort directed toward missile defense.

With a budget of $13.5 million this year, the program is managed by the Office of Naval Research and the Air Force Office of Scientific Research. In addition to the Stanford-TRW project, the program supports a far-infrared free electron laser facility at the University of California at Santa Barbara.

The short wavelength must be accompanied by an increase in electron beam brightness.

The program is also funding the construction of a second independent facility at Stanford, which now has a free electron laser operating in the near-infrared and later will have one in the visible and ultraviolet, and a machine at the National Bureau of Standards that will also cover the near-infrared, visible, and near-ultraviolet. Experimental halls adjacent to all four free electron lasers will give users from other institutions access to the light sources for their research.

Free electron lasers emit their light when a high-energy beam of electrons from an accelerator shoots through a special magnet known variously as an undulator or wiggler because it bends the straight electron beam into a sinusoidal trajectory. The wavelength of the light emitted by the undulating electrons is fixed by the electron beam energy, the magnetic field strength, and the period of the sinusoidal trajectory. In particular, it varies approximately as the inverse square of the beam energy. So, the first requirement for a visible free electron laser is an accelerator of sufficiently high energy.

With typical values of the undulator period and magnetic field, the required energy turns out to be something above 100 million electron volts (MeV). The venerable superconducting linear accelerator at Stanford can boost electrons to 60 MeV and has been used extensively to test free electron laser physics in the near-infrared at 1.5 micrometers. The Stanford-TRW group attacked the problem by developing a beam-recirculation system to nearly double the energy. As explained by Smith, a pulse of electrons enters the linear accelerator from an injector accelerator at an energy of 5 MeV. On emerging from the linac at 60 MeV, the pulse is guided by magnets through a beam pipe back to the front end of the linac. After the second pass, the pulse has an energy of 115 MeV, sufficient to generate green light in the undulator built at TRW.

For some applications, especially those requiring the generation of high-power laser light, the fraction of the electron beam energy converted to optical energy (efficiency) is a major factor in the economics of the free electron laser. Researchers at the Los Alamos National Laboratory demonstrated last year that it is possible to recover a large part of the energy from a pulse of electrons after it has passed through an undulator by decelerating the pulse. The recovered energy is then transferred through a waveguide to the radio-frequency cavities of the accelerator for use on a subsequent pulse. The free electron laser at Santa Barbara operates routinely in a similar mode with an electrostatic accelerator.

The Stanford-TRW group has used its beam-recirculating system to accomplish the same end by recovering the energy directly in the radio-frequency cavities. Whether a pulse is accelerated or decelerated in the linac depends on the timing (phase) of the pulse relative to the radio-frequency electric field in the cavities that drive the linac. By adjusting the pathlength of the recirculated beam, the investigators can adjust the phase for acceleration or deceleration. If the pulse is decelerated, the energy is given to rather than taken from the cavities and can be used to accelerate a new pulse. The group has shown that by this means it can reduce the input power requirement of its linac to 10% of the power needed with no energy recovery.

As in any laser, for lasing to occur, a quantity called the gain must exceed losses. In a free electron laser, the gain depends on the electron beam brightness (measured in amperes per centimeter-radians squared) and the lasing wavelength. It works out that it is not enough just to crank up the energy of the accelerator used to make an infrared free electron laser because the gain of the putative visible laser may decrease too much unless the short wavelength is also accompanied by an increase in electron beam brightness.

In the past, it had been thought that an electron storage ring, which has a high brightness, would be the best machine for a visible free electron laser. In fact, the first visible laser of this type made use of a storage ring at the Laboratory for the Utilization of Electromagnetic Radiation (LURE) in Orsay, France, 4 years ago. However, the comparatively old superconducting linac at Stanford happens to have a very high quality beam with the requisite brightness. Moreover, with improvements in the technology, the performance of conventional linacs is getting to be comparable. A major challenge is to accelerate a beam of high current (needed for high power) and high brightness.

According to Smith, the Stanford-TRW visible free electron laser generated light pulses 3 picoseconds in length with a peak power of about 170 kilowatts at a rate of 12 million pulses per second. Because the highly reflecting mirrors of the cavity normally allow extraction of only a small part of the light, the circulating optical power between the mirrors of the optical cavity was much higher than the output, about 260 megawatts. By using a technique called cavity dumping, it is in principle possible to extract all of this power in one pulse. But because it takes time for the power to build back up in the optical cavity, the frequency of the pulses is reduced, so that the time average output power is not much changed.

The investigators are working on a new injector that can squirt a higher current electron beam into the linac, which may raise the average optical power produced by a factor of 10. Later this year, the group will also try to make picosecond-pulses at still shorter wavelengths of the order of 3500 angstroms by operating the linac at 130 MeV. ■ ARTHUR L. ROBINSON

New Evidence at Wayne State for Superconductivity at 240 K

Not so many months ago when 23 K was the highest transition temperature known, a claim to have found superconductivity at a temperature of 240 K would have been met with at best skepticism. Now superconductivity is well established at temperatures in the 90 to 100 K range and several laboratories have seen hints of superconductivity at still higher temperatures, including 240 K. Researchers are working day and night to isolate the compound many believe is just waiting to be found. While no one is reporting any successes yet, the evidence is mounting that the search will pay off soon.

Two weeks ago at the March Meeting of the American Physical Society in New York, for example, Ching-Wu (Paul) Wu of the University of Houston told reporters that, in certain materials that show a transition to true superconductivity beginning at 90 K or so, his group had seen nonreproducible but nonetheless frequently occurring decreases in the electrical resistivity at temperatures as high as 240 K. Other laboratories have made observations similar to those of Chu, who also said the resistivity sometimes drops by a factor of 100 at the higher temperature.

According to Koichi Kitazawa of the University of Tokyo, the inclination to believe that these suggestive resistivity decreases really do point to a compound with a transition temperature in the neighborhood of 240 K is motivated by an analogy with the situation of the 90 K superconductors only weeks ago. One of these compounds is now believed to have been mixed in with larger amounts of another superconducting compound of the same elements that had a transition temperature of 35 K and gave similarly tantalizing hints in the form of nonreproducible resistivity drops. The hope is that the story will repeat itself at a higher temperature.

Last Friday researchers from Wayne State University weighed in with a claim to have verified the existence of superconductivity at 240 K. The investigators did not isolate the superconducting compound, however, nor did they specify the composition of their material beyond saying that it was in the same yttrium-barium-copper-oxygen family of oxide ceramics, one member of which shows superconductivity above 90 K.

The claim made by J.-T. Chen, Lowell Wenger, Eleftherios Logothetis (also at Ford Motor Company), and their co-workers at Wayne State rests on an infrequently measured effect the researchers call rf-to-dc conversion. As described by Wenger, a radio-frequency electric current passing through the Wayne State samples generates a dc voltage. This is the inverse of the ac Josephson effect in which a dc voltage across a device called a Josephson junction gives rise to an ac current. A Josephson junction consists of two superconductors separated by an exceedingly thin layer of insulating material. Neither the ac Josephson effect nor its inverse can occur in anything other than a superconductor, hence the claim for superconductivity even though the electrical resistivity does not fall to zero.

According to Chen, when the researchers lower the temperature of their material to 240 K, which contains at least two compounds (phases), the resistivity begins to drop, decreasing to about 40% of the original value at a lower temperature. When the investigators continue to decrease the temperature, at 100 K the sample begins to lose its remaining resistivity drops and becomes fully superconducting at about 60 K. The main difference between this behavior and that seen elsewhere apparently is that the Wayne State result is reproducible, whereas resistivity drops in other laboratories are not. The role of the rf-to-dc conversion, which exhibits jumps at both 240 K and near 100 K, is that it directly probes the superconducting phase, whereas electrical resistivity does not unless there is a continuous superconducting path through the sample.

Superconductivity researchers are not going to be convinced by the Wayne State result. They will want to see the new superconducting phase isolated in several laboratories and the classical tests of zero electrical resistivity and magnetic flux expulsion (Meissner effect) applied. Moreover, as Malcomb Beasley of Stanford University points out, poorly characterized materials containing several phases are notorious sources of hopeful reports that later turn sour under close scrutiny. In the case of ac-to-dc conversion, other effects can give rise to similar rectification behavior.

The Wayne State researchers agree that the interpretation of their results is not straightforward. But they also argue that it is possible to disentangle the alternative explanations for rectification by a careful analysis of the way in which the effect depends on such variables as the radio frequency, the amplitude of the current, and the temperature. ■

ARTHUR L. ROBINSON