Bright prospects for laboratory lasers

In physics, power is often the key to new discoveries. That's why particle physicists who hunt for new kinds of matter want to build larger and more powerful accelerators. And it is also why atomic physicists have dreamed of making bright lasers with which to study the largely unexplored interaction between atoms and intense pulses of light.

Three groups of laser scientists are on the verge of achieving that goal. Led by the work of Charles K. Rhodes at the University of Illinois in Chicago, researchers at Princeton (N.J.) University and Los Alamos (N.M.) National Laboratory have produced very intense laser beams by combining recent advances in making very short laser pulses, in focusing laser beams to small spots and in developing lasers that can handle high energies. At Los Alamos, for example, Gottfried Schappert and Robert Gibson announced last week that they have focused a 10^{10}-watt beam from their krypton-fluoride gas laser to a spot less than 5 square microns in size. That gives them what they say is a record-setting intensity of greater than 10^{17} watts/cm^2 in the ultraviolet.

At this intensity, the electric field of a laser pulse that is shined on an atom is strong enough to compete for electrons with the nucleus's electric attraction, called the coulombic field. Ryszard Gajewski, director of the Division of Advanced Energy Projects at the U.S. Department of Energy in Germantown, Md., predicts that within half a year, the three groups will be producing pulses with electric fields that are much greater than the coulombic field.

"We are about to enter a new frontier in physics," he says. "If an electron's behavior is controlled by the laser field rather than the coulombic attraction of the nucleus, that's altogether a new regime. Lord knows what we'll find."

As first suggested by Rhodes, very intense ultraviolet beams from gas lasers will also open the door for making laboratory-scale X-ray lasers. The idea is to pump the X-ray laser with the ultraviolet laser by using its intense pulses to excite atoms to such a degree that they radiate X-rays. Laser physicists have long sought X-ray lasers because their short wavelengths would enable scientists to probe the structure of materials in remarkable detail.

The recent advances in powerful gas lasers have relied essentially on improving conventional technologies. At the University of Rochester in New York, Gerard Mourou and his colleagues have invented a new approach for producing intense, short laser pulses, which he says has given his group the most powerful tabletop laboratory laser in the world. Mourou's group has been working with a solid-state laser — the laser signal is amplified when it passes through a piece of glass doped with neodymium.

According to Mourou, the intensity of beams in these lasers has been limited because at a high intensity, the beam is distorted as it passes through the glass. To get around this problem, scientists have reduced the intensities in the glass by increasing the beam size. But this means that they have had to build very large and unwieldy amplifying systems to accommodate the larger beams.

With Mourou's technique, which he calls "chirped pulse amplification," researchers reduce the intensity by stretching out a laser pulse — making it last 1,000 times longer — before it enters the amplifying glass. After amplification, the researchers compress the pulse back to its original 1-picosecond duration. The same basic technique was used 40 years ago by radar scientists who were trying to use short radar pulses for accuracy while also using the high energies necessary for long range.

With chirped pulse amplification, says Mourou, "we can use a system that is 1,000 times smaller. This means that a system that was the size of a building becomes the size of a table. There's an enormous gain in compactness."

Mourou's technique also means that the power from existing laser systems could increase by 1,000 times — and perhaps by 10,000 times in the near future. He says it could easily be applied to NOVA and other large lasers being developed for fusion, for X-ray laser work and for weapons simulation research (SN: 5/31/86, p.348).

Wayne Knox, at AT&T Bell Laboratory in Holmdel, N.J., calls Mourou's technique "something very significant because it is a totally different approach." The significance of Mourou's work, he says, is not only what he has already achieved, but how far he may be able to go in the future.

— S. Weisburd

Early hearing loss and brain development

Severe damage to an infant's or fetus's inner ear can trigger damage to certain areas of the brain and impede brain development, according to studies with chicks and chick embryos by researchers in Seattle. Exposing adult chicks to the the same type of ear damage — roughly equivalent to that induced by extremely loud noise — results in no such brain damage, reports Edwin W. Rubel, professor of otolaryngology at the University of Washington School of Medicine.

While he says it is premature to directly extrapolate these findings to humans, Rubel nevertheless suggests that "human fetuses and infants also may be hypersensitive to certain types of noises and that this sensitivity changes during the course of early development." He reported his results recently in Chicago at the annual meeting of the American Association for the Advancement of Science.

In a series of experiments, Rubel and his colleagues surgically destroyed inner-ear cells in chick embryos and in baby chicks up to 6 weeks of age. (The same type of destruction could be triggered by "high-intensity" sound, he says, equivalent to that found in some industrial settings or "on a jet runway.") Left intact were neurons that projected from the inner ear into the brain.

As little as two days later, the researchers discovered "dramatic cell loss" in the cochlear nucleus of the brainstem, Rubel reports. In addition, the brain cells that did remain in the affected regions had atrophied. "We found fewer and smaller neurons in areas of the brain corresponding to the areas where inner ear cells had been destroyed," he says.

In addition, he and his colleagues found that the affected brain areas displayed no protein synthesis and had retarded levels of certain enzyme metabolism. These changes were not seen in chicks older than 6 weeks.

"This tells us that early in life, [brain cells] not only receive information from the periphery [the ear] but are metabolically dependent on stimulation from the periphery," Rubel said in an interview. "At some point in life — at least in the chicken — there is a metabolic uncoupling, although the information coupling remains the same."

Rubel's latest work is based on a number of previous studies, including his own, suggesting that the inner ear's cochlea codes for sound differently in the infant than in the adult. Those studies found that whereas in the adult, the base of the cochlea responds to high-frequency sounds and the apex of the cochlea to low-frequency sounds, the opposite is true in infants and embryos.

Whether or not these shifts in sensitivity are involved in protecting the adult from ear-damage-induced brain damage is not known.

"The question is," Rubel says, "can we find out how adults are protected and can we provide this protection for young children?" Although there are conflicting views regarding fetal hearing, Rubel says, "we do know that a lot of low-frequency sound gets into the uterus from the external environment and that the baby is hearing." And though he cautions against jumping to conclusions from his chick studies, he adds, "If it were my wife, I certainly wouldn't let her use a jackhammer."

— J. Greenberg

Science Service, Inc. is collaborating with JSTOR to digitize, preserve, and extend access to *Science News*. www.jstor.org