Free-electron lasers gain—highly

Lasers, which produce intense, highly amplified beams of light, have made themselves extremely useful in science and technology in the quarter-century since they were invented. Scientists and engineers would like to have lasers at just about any wavelength, but a major drawback in the technology has been that lasers are generally not tunable. To change the wavelength, inventors have had to change the lasing substance; each substance has its own characteristic wavelengths of emission. The few that are tunable have fairly short ranges.

For general tunability many scientists look to the free-electron laser, which gets its amplification from electrons moving freely, not bound to atoms like the electrons that do the amplifying in solid, liquid or gas lasers. There are a fair number of free-electron laser experiments in progress around the world, from Siberia to California, and many of them have operated successfully in 1984, according to John J. Madey of Stanford University, who reviewed the subject at last week's meeting in San Francisco of the International Conference on Lasers '84.

Only two of these experiments, however, have so far shown large amounts of amplification—one at the Naval Research Laboratory (NRL) in Washington, D.C., and one at the Lawrence Livermore National Laboratory (LLNL) and operated by physicists from LLNL and the Lawrence Berkeley Laboratory (LBL). Of these two, the LLNL-LBL experiment achieved a record amplification gain.

Andrew M. Sessler of LBL, who described the LBL-LLNL experiment at the meeting, cited the amplification of a microwave signal from 30,000 watts to 80 million watts (80 megawatts). The NRL experiment, described by Steven Gold of NRL, also reached amplification levels of tens of megawatts. Both experiments operated at the same wavelength, 8.6 millimeters — which corresponds to a frequency of 35 gigahertz.

A free-electron laser takes a beam of energetic electrons (usually from some kind of accelerator) and puts them through the field of a wiggler magnet. The wiggler field reverses polarity every so many millimeters, so that the passing electrons feel an undulating field. This undulating field makes the electrons wiggle back and forth perpendicular to the direction in which they are going. Such wiggling makes them radiate electromagnetic radiation (called synchrotron radiation).

If there is also present a beam of electromagnetic radiation whose frequency resonates with that of the electrons, the electrons will radiate in such a way as to strengthen that radiation. The resonant frequency depends on the strength of the wiggler field and the energy of the electrons, so such a device is tunable, in principle, to almost any wavelength. The Naval Research Laboratory experiment uses an extra magnetic field, which, in the opinion of the LBL-LLNL group, will not work at shorter wavelengths. The LBL-LLNL group calls its experiment the only "pure" free-electron laser that has achieved high amplification.

However, there are those that work at shorter wavelengths, if only at a few-percent amplification. Madey cites an experiment at the University of California at Santa Barbara that works at 400 micrometers (0.4 millimeters) and one at Yerevan in Soviet Armenia that runs at 40 micrometers (0.04 millimeters). Technically it is easier to start at the high wavelength end, but what the experimenters would really like to see is a march down through the infrared and visible ranges into the ultraviolet. A representative ultraviolet wavelength might be 800 angstroms or about a ten-thousandth of the wavelength of the present LBL-LLNL and NRL experiments.

The prospect of shorter wavelengths—particularly in the ultraviolet, where there are now few lasers—occasioned spirited discussion at the meeting. The difficulties may be severe, but progression to shorter wavelengths and higher amplification seems possible. —*D. E. Thomsen*

Bronze Age trade surfaces from wreck

Archaeologists from the United States and Turkey have uncovered a treasure trove of Bronze Age trade goods among the remains of a cargo ship that sank in the Mediterranean Sea about 1400 B.C.

"This is the most important ancient shipwreck ever found in the Mediterranean," excavation director George F. Bass this week told a press conference held by the National Geographic Society in Washington, D.C., a cosponsor of the expedition. "It greatly extends our knowledge of Bronze Age trade, and we've only opened a small part of the ship's hull so far."

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Pottery, including a Canaanite amphora (top), was among the artifacts discovered in a 3,400-year-old shipwreck.

The wreck was found last summer off a rocky cape in southern Turkey. The investigators learned of the ship from the report of a Turkish sponge-diver who said it contained objects resembling "metal biscuits with ears."

The objects turned out to be about 150 four-handled copper ingots, which were once used to shape bronze tools and weapons. In addition, the investigators found glass and tin ingots, pottery, gold artifacts, ancient Greek jars and pieces of tusk from an elephant and from a hippopotamus. A two-handled Greek pottery cup helped to date the wreck to at least as far back as the 15th century B.C.

"The mix of artifacts on the boat puzzles us no end," says anthropologist Bass of Texas A&M University in College Station. Along with the Greek artifacts, pottery from two other cultures — Cypriot and early Phoenician, or Canaanite—has been found. As a result, it is hard to know where the traders came from, notes Bass. The ship was probably Greek, he says, but there is still disagreement over whether there were Semitic traders in the Bronze Age, from 3000 B.C. to 1000 B.C. The scientists also do not know whether the ship was engaged in a "free market" type of trade or if it was exchanging goods between eastern Mediterranean rulers.

But the find provides the earliest evidence of a trade in glass ingots. Some of the 36 Canaanite jars, or amphoras, recovered so far contain a variety of products — glass and amber beads, several types of seeds and pitch, an arsenic compound. Some of the Cypriot pottery was stacked in a 5½-foot-tall storage jar that was used like a china barrel, says Bass.

Several bronze weapomds and gold objects that may have come from the area around Syria and Palestine were also on board, he adds. And for the first time, investigators have had a look at a row of six stone anchors used at the time, each weighing about 600 pounds.

No human remains have been found in the wreckage so far.

Bass speculates that the ship was driven to the rocks by strong winds while trying to round a peninsula. There it settled to the bottom without capsizing. Today it lies about 145 feet below the surface. Its remains, says Bass, prove that Bronze Age shipbuilding techniques were essentially the same as those used by the Greeks 1,000 years later. —*B. Bower*