



Interim target chamber at the University of Rochester Laboratory for Laser Energetics uses the six beams of the Zeta neodymium-glass system. In December, 24 beams are expected to operate.

the laser plasma x-ray source makes it a unique tool. One could, for example make x-ray diffraction patterns of a biological specimen to study the temporal development of stimulated structural changes with better than nanosecond resolution. Lubin notes that photoreceptor membranes have picosecond response times.

In all three of its stages, Omega can operate with a repetition rate of about 30 minutes (and could run 18 hours a day), unlike the Livermore facility, for example, which has a repetition rate of several hours. The 30-minute rep rates are possible also with the Los Alamos, KMS and NRL lasers. Lubin emphasizes that the short duty cycle allows significantly greater data-gathering capability. He feels that the reproducibility of inertial-confinement data is important—that one needs 20 or 30 data points to draw reliable conclusions, particularly in trying to optimize target design.

The Rochester lab also has a variety of diagnostics available: on-target and target-reflected energy, prepulse characterization to less than 1 microjoule within 1 nanosec of the laser pulse, incident and reflected pulse time history, and on-target irradiation profile. The target tank has x-ray streak and pinhole cameras, detectors and spectrometers, nuclear-reaction product detectors and light and plasma calorimeters.

Those interested in using the facility should contact Wilson at the lab, who will advise potential users how to seek support. Research in these fields has been traditionally supported by universities and by government agencies, such as DOE, the Department of Defense and NSF. The Foundation, for example, has indicated that it will consider proposals

from potential users in the normal competition occurring in each appropriate program. Such an approach has been used in the past for high-energy physics, in which NSF supports users at DOE laboratories.

—GBL

Progress on deep-sea neutrino detection

For several summers, a group of physicists, astrophysicists and oceanographers interested in using the oceans to detect ultrahigh-energy cosmic-ray neutrinos have been meeting to exchange ideas. Their interest arises because clean seawater could provide the massive detector needed to observe low fluxes of weakly interacting, deeply penetrating neutrinos (PHYSICS TODAY, April 1976, page 18). The detector volume, about one cubic kilometer, located 5 km or so underwater, would avoid gross interference from ordinary cosmic rays. Organized as DUMAND (Deep Undersea Muon and Neutrino Detector), the group has been formulating the questions that would need to be answered in any feasibility study of the project. The most recent workshop¹ took place 24 July–1 September at the Scripps Institution of Oceanography, La Jolla, with about 90 participants from the US, the Federal Republic of Germany, Japan and the Soviet Union.

Although the project has no specific funding as of yet, some parameters have been determined, explained Frederick Reines (University of California, Irvine), chairman of the DUMAND executive committee. For example, to detect neutrinos by means of the Cerenkov light produced by the secondary muons and hadronic cascade, the transparency of the

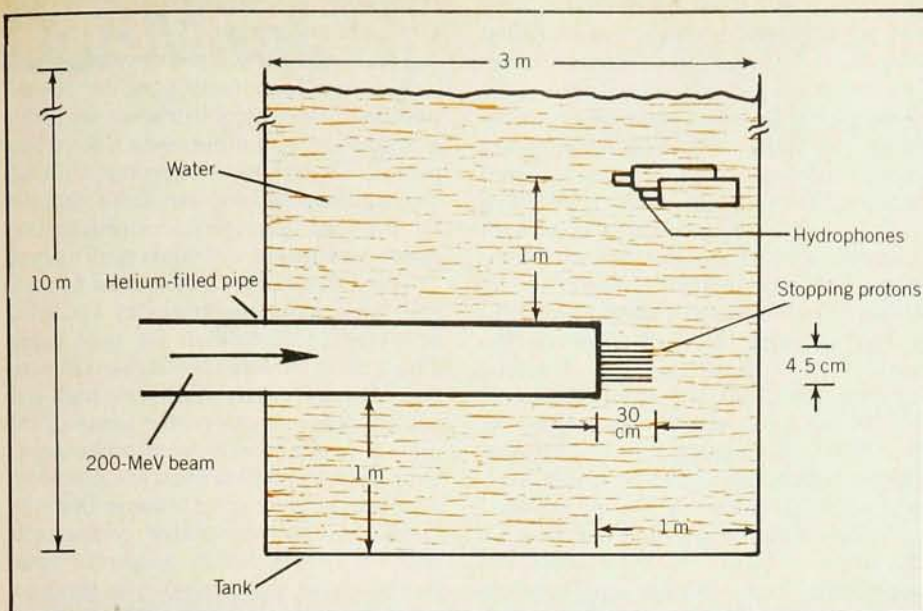
water is critical. Water with optimal properties has been found near the Hawaiian Islands.

One working group concentrated on practical construction and deployment techniques and came up with several new schemes. The least expensive and most reliable of these, according to Reines, would use a drill ship to implant and connect preassembled packages. The workshop participants came up with a standard DUMAND array: a hexagonal arrangement of detectors that is being used in all studies of design problems. The array contains about 25 000 optical detectors in a set of string-like patterns. And, for the first time last summer, data processing was discussed at length.

The total cost of this DUMAND array is estimated at \$50–100 million. Grants from the US Department of Energy, NASA, NSF and the Office of Naval Research partially supported the workshops, and proposals are in to support a full feasibility study. In addition to Reines, the DUMAND executive committee includes Howard Blood (Naval Ocean Systems Center, San Diego), Hugh Bradner (Scripps), John Learned (University of California, Irvine, and University of Wisconsin, Madison), Arthur Roberts (Fermilab) and George Wilkins (Naval Ocean Systems Center, Kaneohe, Hawaii).

Acoustics. A development closely related to DUMAND is the recent determination that acoustic detectors could be feasible for high-energy neutrinos. This idea was first suggested by Theodore Bowen (University of Arizona, Tucson) and, independently, by Boris Dolgoshein (Moscow Physical Engineering Institute), and discussed at an earlier DUMAND summer session. Stimulated by these discussions, a group of physicists from six universities have now done some experiments at Brookhaven National Laboratory and at Harvard University, with protons from three different accelerators—the 200-MeV linac at Brookhaven, the 158-MeV cyclotron at Harvard and the 28-GeV proton fast-extracted beam at Brookhaven. The proton beams simulate the particle showers produced by neutrino interactions. These experiments were reported in November at the joint meeting of the Acoustical Society of America and the Acoustical Society of Japan in Honolulu.²

The group found that the energetic charged-particle beams produced a signal that could be detected with hydrophones, and that the acoustic wave observed agreed with the predictions of a thermal expansion model. This agreement is important because significant contributions from such phenomena as microbubble formation could complicate data analysis. As Lawrence Sulak (Harvard) of the acoustics-studies group explained to us, knowledge of the responsible mechanisms is needed to design an



Acoustic detection. 200-MeV protons enter water tank from a helium-filled pipe and are stopped within 30 cm. Two hydrophones, at different path lengths from the beam, pick up the sharp clicks produced by beam. Data are consistent with predictions of a thermal-expansion model.

acoustic detector for neutrino interactions. The threshold for acoustic detection, according to the proton-beam studies, appears to be about 10^{14} eV for one microphone at close range and about 10^{16} eV for the DUMAND array. This energy is much higher than what would be deposited by atmospheric neutrinos, but is attractive for ultrahigh-energy neutrino astrophysics. Acoustic attenuation is much lower than optical attenuation, so that an acoustic detector, with a volume of hundreds of cubic kilometers, could observe those sources that emit energetic neutrinos (10^{15} – 10^{16} eV) at too low a rate to be optically observable.

Other possibilities. Astrophysicists at the DUMAND workshop suggested a growing number of potential sources, including pulsars in binary systems, quasar explosions, steady emission from quasars and active galaxies, pulsars in young, opaque supernova shells and even from solar flares on the far side of our Sun. They stressed the limits on these speculations that would be set by comparison with observations in gamma-ray astronomy.

Cosmic-ray neutrinos are of interest to high-energy physicists as well as to astrophysicists: The very high-energy neutrinos could be used as probes to study the weak interaction, and to see what happens at the extreme energies not attainable at any accelerator. But for this type of experiment, detectors would need great sensitivity.

To improve the present limit on the lifetime of the baryon, a collaboration among Irvine, University of Michigan and Brookhaven is being formed to do such an experiment. (The Irvine group found a limit of 10^{30} years for a particular postulated decay mode.) At the same time, the DUMAND group is considering whether an even more sensitive experiment might be

possible deep underwater with a small DUMAND-type detector.

What of the possibility of using large vats of liquid as land-based detectors for accelerators? The acoustics group suggests that these detectors be used as charged-particle monitors in accelerator beams, or for localizing the dosages in proton radiotherapy, or as hadronic shower detectors in high-energy accelerators, such as the Fermilab Energy Doubler. Here the question appears to be whether the advantages of acoustic detectors—that they are large and cheap—will be sufficiently attractive for accelerator neutrino physics. Such studies are now planned or underway at the Lawrence Berkeley Laboratory (the Bevalac), at Fermilab and at Brookhaven. —MSR

References

1. A report of the workshop, edited by Arthur Roberts, will be available shortly.
2. L. Sulak, T. Armstrong, H. Baranger, M. Bregman, M. Levi, D. Mael, J. Strait, T. Bowen, A. E. Pifer, P. A. Polakos, H. Bradner, A. Parvulescu, W. V. Jones, J. Learned, Nucl. Instr. Methods, to be published.

Electron-hole droplets

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live longest there. Drops have also been observed in silicon and gallium phosphide, but their lifetime is much shorter. Maurice Rice of Bell Labs told us that recent experiments and calculations point to the formation of drops in other indirect-gap, polar materials such as silicon carbide and silver bromide; for direct-gap semiconductors, the evidence suggests that drops may be formed in cadmium sulfide, cadmium selenide, gallium arsenide, and others, but there is still some

debate about the conclusiveness of this evidence.

Because the drops "evaporate" quickly, due to recombination, they must be replenished. Usually this is done simply by raising the intensity of the exciting light to far above the threshold for creating drops. The high power dumped into the crystal also creates phonons that exert forces on the drops. To observe the behavior of the drops in the absence of forces due to phonons, Robert Westervelt, in Carson Jeffries's group at Berkeley, creates droplets in ultrapure germanium with a brief, intense pulse of light. The crystal is also illuminated with another, steady beam of light, whose frequency is above the band gap, but whose intensity is far below the threshold for droplet formation. Once the droplets are formed, the steady, low-level illumination replenishes the exciton gas, and thereby the droplets, to replace the pairs lost by recombination. In contrast to their behavior in other experiments, the drops move extremely slowly under these conditions. Their diffusion is many orders of magnitude slower than had been anticipated from earlier experiments: At the Edinburgh conference Westervelt reported that the diffusion constant is less than 10^{-9} cm²/sec. The drops diffuse by less than their radius in a second. Jeffries told us that the drops appear to be trapped, perhaps by impurity sites, and that they would hop only slowly from site to site in the absence of forces. The relaxation time for droplet motion is also very short; as Wolfe put it, the crystal is a highly viscous medium for the motion of the drops. (The viscosity is analogous to the ohmic resistance.)

The phonon wind. In 1971 L.V. Keldysh, a theorist at the Lebedev Institute in Moscow, pointed out that acoustical phonons interact strongly with the droplets. At the low temperatures (about 2 K or less) at which droplets are observed, a flux of relatively low-frequency, but non-thermal phonons will exert a force sufficiently strong to move the droplets through the crystal, what Keldysh (in 1976) called the phonon wind. The wind was first examined in experiments by V.S. Bagaev, also at the Lebedev Institute, and Keldysh. Three very different experiments have now provided very clear evidence for the phonon wind.

Hensel and his coworkers at Bell Labs create a stationary cloud of drops by illuminating one face of a germanium crystal with an infrared beam (1.52 micron) from a He-Ne laser. Because the beam penetrates about 1 mm into the crystal, the cloud has a cylindrical shape. To investigate the drops, Hensel and Dynes then create a large number of phonons (a heat pulse) at one of the perpendicular crystal faces by illuminating it with a brief (fractions of a microsecond), intense pulse of light. An aluminum bolometer on the opposite face detects the