

With a transverse flow system such a laser could presumably be made to run continuously, and because it is scalable in all dimensions extremely high output could be obtained. The limit is probably set by eventual electrical breakdown of the gas mixture by the laser radiation itself, which might occur at high energy densities.

The Los Alamos devices are amplifiers for short pulses, not laser oscillators, but they also use an electron-beam-controlled discharge. Charles Fenstermacher, Murlin Nutter, Wallace Leland and Keith Boyer reported to the Gainesville meeting on their gain measurements at 10.6-micron wavelength in a 5-atmosphere mixture of He, N₂ and CO₂ in various proportions.

The Los Alamos amplifier system will be driven by a TEA ("Transversely Excited Atmospheric pressure") CO₂ laser that delivers 1 millijoule per pulse in 1-nanosec pulses. With four stages of amplification the output energy is expected to be 1000 joules, still in 1-nanosec pulses. The first stages of the device are being checked out and achievement of 1000-joule nanosec output is expected within the year.

"Our device," Fenstermacher told us, "is essentially a short pulse, single-shot arrangement. The pumping time to build up inversion in the CO₂ levels is typically 5 to 10 microseconds; so you pump for this length of time with the external electron beam, storing energy in the laser levels. Then you hit the amplifier with the short pulse from the TEA laser to dump the energy. There's no way you could get that amount of energy [1000 joules] into the machine in one nanosecond."

The laser development effort at LASL forms part of a larger program to study fusion feasibility. The large laser system will be used to investigate plasma absorption and energy transfer processes in appropriate target materials. Similar studies have been underway with glass lasers for some time (see, for example, *PHYSICS TODAY*, November 1968, page 57, for a description of the work at the Lebedev Institute). But Fenstermacher believes that glass lasers will reach their energy limit below the breakeven point for laser-induced fusion.

IBM's laser, reported at Gainesville by Rod Hodgson and Russell Dreyfus, also has electron-beam excitation but differs from the others in that no electric field is applied to the discharge to sweep electron-ion pairs through the gas. This hydrogen laser uses a commercial electron-beam generator as its energy source. A 3-nanosec pulse of 400-keV electrons, total current about 10⁴ amps, is confined by an axial magnetic field and fired down a 1.5-meter tube containing 10–100 torr of hydrogen. These electrons either ionize the gas molecules or excite vacuum-uv levels by collision, and they can make many such collisions

before they degrade to thermal energies. Explaining the device to us, Hodgson said: "When a discharge produces breakdown in the gas, the impedance drops and it is difficult to get much more power into it. On the other hand, most of the electron-beam energy can be used efficiently."

At the Lebedev Institute, Nikolai Basov's group is experimenting with electron-beam controlled atmospheric-pressure CO₂ lasers too. But they are also working with a new high-pressure (several atmospheres) xenon laser on the same principle as the Avco device. Xenon lasers are interesting because of their high efficiency compared to CO₂. The higher-energy laser level is one of the bound molecular excited electronic states (Xe₂*), and the lower level is the repulsive ground state of molecular Xe₂. This Xe₂ ground state is so close in ener-

gy to the ground state of Xe that the upward transition, Xe to Xe₂*, is only a little more energetic than the downward one, Xe₂* to Xe₂. This can be thought of as a "pseudo-two-level" system. If efficiency is defined as:

$$\frac{\text{photo quantum energy}}{\text{electron excitation energy}}$$

the ratio for xenon is close to 90%. Basov's group has already measured an efficiency of 50% at 1600 Å. In CO₂ on the other hand, we have a true three-level system in which the transition from the ground state to the upper level, 0.25 eV, is considerably greater than the downward transition to the lower laser level, 0.1 eV. Theoretical efficiency is therefore 0.10/0.25 = 40%. Experimentally measured efficiencies of CO₂ lasers are about 25% at best. —JTS

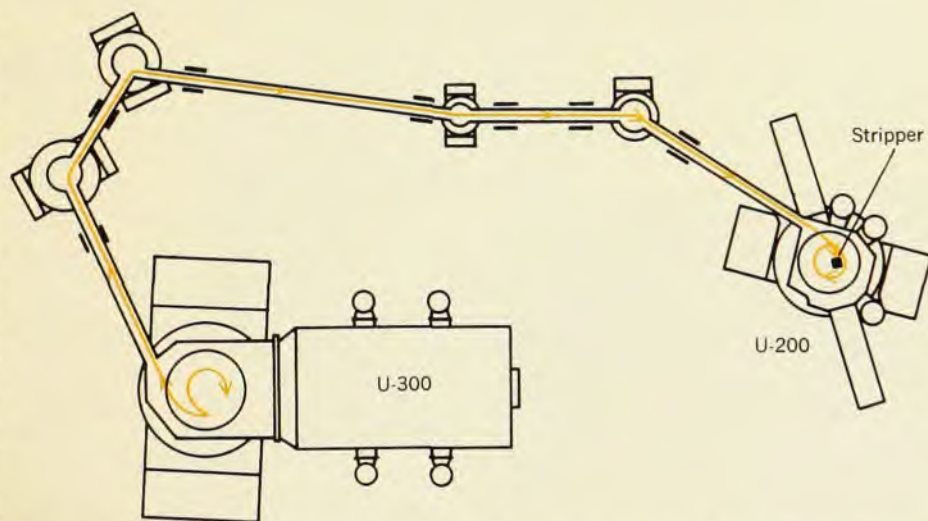
Dubna cyclotrons paired to accelerate xenon

Xenon ions have been accelerated to 7 MeV/nucleon or a total energy of 925 MeV, an energy sufficient to surmount the Coulomb barrier in any known nucleus. The xenon ions, with Z of 54, are expected to be very effective in the attempt to make supertransuranic elements near the island of stability.

To produce the xenon ions, Georgi Flerov and his collaborators at the Joint Institute for Nuclear Physics in Dubna hooked two cyclotrons together. The experiment was described late in October by Ivo Zvara of Dubna at the Argonne transplutonium-elements conference and at the Oak Ridge International Conference on Multiply Charged Heavy Ion Sources and Accelerating Systems.

The experiment was done with the U-300, a 3-meter-diameter cyclotron completed in 1960 and the U-200, a 2-meter cyclotron that was converted three years ago to sector focusing. The two machines, about 70 meters apart, were connected. In the center of the U-300 the Dubna group put an ion source that made (Xe¹³²)⁸⁺. The ions were then accelerated to 0.9 MeV/nucleon; the beam had an intensity of 3 × 10¹² particles/sec.

In the center of the U-200 the experimenters put an aluminum foil, 0.5-microns thick. The xenon was stripped in that foil to +28. Then the (Xe¹³²)²⁸⁺ was accelerated to near final radius. The intensity was 3 × 10⁹ particles/sec. The beam was not extracted



Acceleration of xenon ions at Joint Institute for Nuclear Physics in Dubna. The U-300 and U-200 cyclotrons are connected by a 70-meter transport system that includes a change of elevation as well as numerous bends. So far the (Xe¹³²)²⁸⁺ beam energy is somewhat less than 7 MeV/nucleon at an intensity of 3 × 10⁹ particles/sec. For (Xe¹³⁶)³⁰⁺, full energy of 7 MeV/nucleon has been obtained with an intensity of 3 × 10⁸ particles/sec.

nor was it used in any experiments.

Besides the Xe^{132} , the experimenters accelerated (Xe^{136})⁹⁺ in the U-300 and (Xe^{136})³⁰⁺ in the U-200, achieving an intensity of 3×10^8 particles/sec and an energy of 7 MeV/nucleon or a total energy of 925 MeV.

As a very preliminary first discovery experiment the Dubna group used their xenon-136 beam to bombard a thick uranium target and look (unsuccessfully) for a supertransuranic element. For isotopes with half lives between one hour and 10 days, they find that the cross section for production was less than 10^{-31} cm². The experimenters looked for elements that were homologs of the elements from iridium to bismuth. They saw no spontaneous fissions or long-range alpha particles.

The search for supertransuranics has been a continuing race between Dubna and Lawrence Berkeley Laboratory, which had hoped to make xenon ions with the new super-HILAC about the same time as Dubna. Albert Ghiorso and his collaborators at LBL hope to be running experiments with their new machine this month. Ghiorso would like to use targets heavier than uranium, such as Pu²⁴⁴ and Cm²⁴⁸, to get as close as possible to the island of stability.

—GBL

Laser plus iron target: broad-band x-ray source

By bombarding a thick iron target with a high-power laser, a broad-band source of x rays has been produced. The conversion efficiency of 1.06-micron laser light into x rays is at least 10%, probably 15-20% and possibly 30-40%, according to Philip Mallozzi (Battelle Memorial Institute, Columbus), who announced his results at the Esfahan (Iran) Symposium on Fundamental and Applied Laser Physics in September.

Above 1 kV the output was mainly spectral lines, Mallozzi said, and he believes that the major portion below 1 kV was probably lines, too. At ener-

gies above 1 kV, the conversion efficiency is about 5%.

Some observers believe that the Battelle result is a big step forward toward a brute-force x-ray laser. One possibility is to use a broad-band x-ray source of very high intensity as a laser pump.

Mallozzi uses a Hadron CGE-640 neodymium-doped glass laser, pulsing it at 100 joules in 1 nanosec. The beam passes through an f/1 lens, strikes a target at 45 deg with respect to the incident beam, and a plasma is produced in the target at the laser focus. The target is a 1-cm-thick slab, essentially infinitely thick to the laser. Mallozzi has tried targets of chromium, nickel, aluminum, lead and gold and obtained x-ray conversion with varying efficiencies. With chromium, he sees essentially the same efficiency as with iron.

The distribution of internal states in the atom, rather than the gross properties of the target, are what determines the output, Mallozzi says. That is, the spectrum and conversion efficiency depend on the atomic number Z of the target, and one can expect large conversion efficiencies from any material with Z above 10, provided one properly adjusts the precursor pulse or foot, a low-power pulse that precedes the main pulse. The purpose of the foot is to produce plasma so that the main pulse will strike a plasma rather than a solid.

For iron, the material used for most of the Battelle studies, Mallozzi finds that with no foot he gets very soft x rays. With a long foot he gets a few harder x rays. With full parametric variation of foot size he gets an optimal value at 8-10 nanosec pulse duration.

Using a computer analysis to solve the rate equations resulting from a microscopic description of all the principal collisional and radiative processes in the experiment, Mallozzi finds good agreement between the calculation and experiment.

Mallozzi has also tried experiments with pellets, but most of the emphasis has been on slabs because he feels they are more useful in gaining basic data, although they may not be the best geometry. Similarly, he has concentrated on iron, although it may not be the best material.

Laser bombardment of high- Z materials is promising for an x-ray laser, Mallozzi feels, and also has other uses that he cannot discuss. In fact Battelle's emphasis has primarily been on these other uses, rather than as an approach to an x-ray laser. Mallozzi has mainly been trying to make a broadband source.

Because he has achieved good conversion efficiency and considerable line output, he believes that by making a different selection of targets, most of the energy could be made to come out in a few lines. He notes that when you

pulse a material rapidly compared to the lifetime of the states involved, you would expect to produce metastable states. Mallozzi has not yet searched for such superradiant levels in the laser focus. If they are there, the device would be close to a laser. The only problem left, he said, would be to make a cavity.

The interaction of a laser beam with high- Z materials is also useful for controlled fusion. Mallozzi feels that the technique will play a key role in lowering the threshold laser energies for achieving fusion. Although most of the emphasis in this effort has been with light materials, Mallozzi envisions using a high- Z material in conjunction with deuterium and tritium, perhaps in different layers.

—GBL

More power and smoother surface for Arecibo dish

The National Astronomy and Ionosphere Center at Cornell, which runs the Arecibo Observatory in Puerto Rico, is planning a series of improvements in the radio-telescope radar system which, according to director Frank Drake, are expected to raise its sensitivity by a factor of 2000. Drake said that the upgrading program will enable the center to make radar maps of Venus with a resolution of about 1 km—comparable to the best currently-available earth-based maps of the moon—and to map Mercury, Mars and the major satellites of Jupiter.

Atmospheric studies of Jupiter will be possible by bouncing a signal off one of Jupiter's moons and through the planet's atmosphere as the moon is occulted by Jupiter.

Irwin Shapiro of MIT noted that the improvements to the radio telescope will be particularly welcome because they will permit improved measurements of the rate of precession of Mercury's perihelion, which has been used to measure secular effects predicted by general relativity.

The radar transmitter power will be increased from 150 kW to about 1 MW and the transmission frequency will go up from 430 MHz to 2400 MHz. The curvature of the 1000-ft-diameter dish will be smoothed out so that the radio telescope will be able to receive frequencies of about 3000 MHz, reducing the minimum usable wavelength from 50 cm to 6 cm. Reception will be further improved by installation of a more sensitive maser receiver along with a better antenna feed system.

Improvements are expected to be completed in 1974. NSF, which funds the operations of the Arecibo center, is paying for the project to smooth out the dish. NASA is providing money for the other improvements.

—SMH□



Hadron CGE-640 neodymium-doped glass laser is pulsed at 100 joules in 1 nanosec. Beam strikes target and produces broad-band x-ray source.