The Wraps Come Off Continuous High-Power Lasers

The latest kind of pump for a laser is a rocket engine; such a gas-dynamic laser has produced continuous power of 60 kilowatts in multimode operation. Many had suspected that such high-power devices were being built, but the research was classified until the Washington APS meeting, where Edward Gerry of Avco-Everett Research gave an invited paper.

The highest continuous power previously reported has been about 10 kilowatts, with electrical pumping in a 200-meter-long carbon-dioxide laser. Although laser powers as high as 10^{11} watts have been produced (100 times the total electrical generating capacity of the US), they last only 10^{-12} sec.

Three kinds of gas-dynamic lasers have been made. Electrically pumped lasers use convection to remove waste energy; the faster the gas flow the higher the average power capability. Such lasers have been built over a wide range of wavelengths. At the APS high-power laser session, Anthony De Maria of United Aircraft Research Laboratories said that he and his collaborators have produced 11.5 kilowatts of continuous power from a CO_2 mixing laser, which emits at 10.6 microns. Their laser has a channel 100 cm × 2 cm and gas flows of 100–200 meters/sec; output efficiency is about 14%. Efficiencies as high as 19% have been obtained at power levels of a few kilowatts.

In high-power chemically pumped systems, besides removing waste energy, flow is used to replace the reactants as they are used up and to vary temperature and reaction rate.

Avco uses thermal pumping, in which the flow itself creates the population inversion by rapid expansion of the gas through a supersonic nozzle. In a typical experiment, a mixture of 9% CO_2, 90% N_2 and 1% H_2O (which acts as a catalyst) is heated to 1400 K and compressed to 17 atmospheres in a rocket engine. This can be done by combustion of suitable fuels in an open-cycle system.

Most of the energy is stored in the nitrogen, whose deactivation time to the ground state is very long. Because carbon dioxide is a linear triatomic molecule it has three basic modes of vibration: asymmetric stretch (the upper laser level), symmetric stretch (lower laser level) and bending. The single vibrational mode of nitrogen, whose lowest level lies fortuitously close to the upper laser level of CO_2, can exchange energy rapidly with the upper level.

To cause population inversion, one must expand the gas mixture through the nozzle much faster than the combined relaxation time of the upper level coupled with nitrogen. Meanwhile, because the catalyst is present, the lower level can relax in a time less than or comparable to the expansion time. As the upper level is depleted it is refilled by the nitrogen excited state. Typical parameters were: nozzle throat of 0.8 mm, area ratio of 14, downstream Mach number of 4, pressure of 0.1 atmosphere and room temperature. An early CO_2 laser produced 6 kW. Typical efficiency of energy conversion is about 1%.

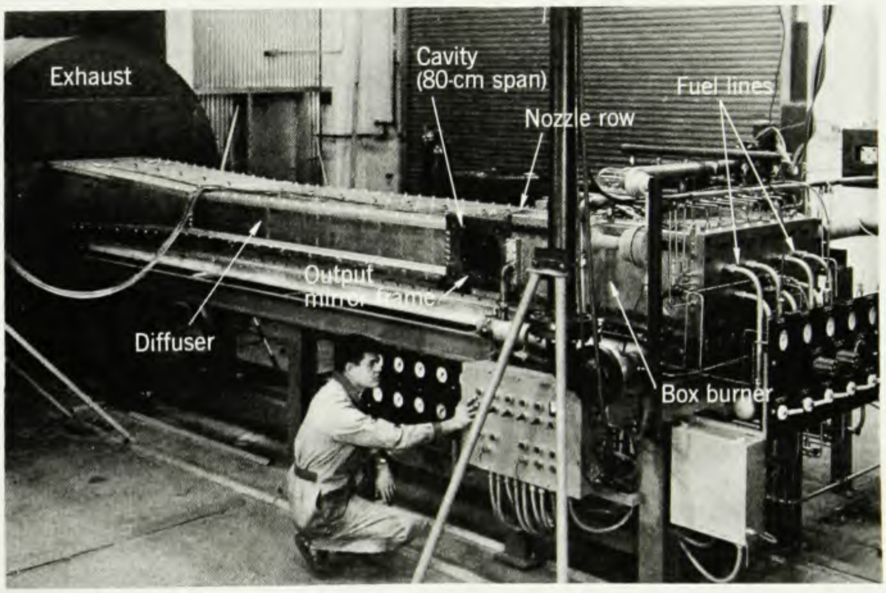
The most powerful thermally pumped gas dynamic laser described by Gerry uses carbon monoxide as fuel. Mirrors are placed 80 cm apart; the gas has a flow-rate of about 30 lb/sec and speed of 1300 meters/sec. The laser produced 60 kW of multimode power and 30 kW in a beam of 20 arc-sec divergence and 30-cm aperture.

Who needs such continuous high power? Obvious applications are for welding and for cutting steel plates to a desired shape, even while forming is going on. Gerry says the idea of using a high-power laser to knock out an airplane or missile has not been tried by Avco; atmospheric turbulence limits collimation over long ranges.

For scientific and industrial applications, De Maria noted, the electrically pumped laser is more appealing because of its size, simplicity, efficiency, low noise level, safety and versatility.

Most experiments do not need kilowatts of average power. For nonlinear optics observations such power would simply vaporize the sample. But high peak powers should be valuable. Electrically pulsed CO_2 lasers yielding megawatts of peak power and tens of joules of energy in microsecond times are presently operating.

Once you start to pulse high-power gas lasers, however, you appear to be limited in the achievement of high peak powers by factors not operative with solid-



AVCO GAS-DYNAMIC LASER uses thermal pumping, in which the flow itself creates population inversion by rapid expansion of gas through supersonic nozzle. Fuel-air mixture is ignited. Then hot, high-pressure carbon monoxide is expanded through nozzle row into laser cavity. Mirror arrays at opposite ends of cavity collect and direct stimulated emission until full power is extracted through hole. This laser has produced 60 kW of continuous multimode power. The Avco work was recently declassified.

state devices—for example, stored energy densities and characteristic line widths. So pulse durations shorter than tens of nanoseconds have not been produced with gas lasers. Some experimenters think they may be able to overcome these limitations, though. —GBL

Does the Microwave Background Have a Hump in its Spectrum?

The three-degree blackbody radiation may have a hump in its spectrum at about 1 mm, just where it peaks. Whether or not it's there, and if so, how it got there, is an intriguing mystery.

At the Washington APS meeting James Houck (Cornell University) described in an invited paper two rocket observations that he, Kandiah Shivanandan (Naval Research Laboratory) and Martin Harwit (Cornell) made.[1,2] With a broad-band spectrometer sensitive over 0.5–1.3 mm they found a flux 50 times higher than expected.

Houck says the extra signal "may have been due to instrumental effects, the thin atmosphere [in which the rockets flew—170 km above the earth], or some unexpected emission process in the solar system or our galaxy. There is also the possibility that the radiation is an unexpected feature of the 'Big Bang.'"

Subsequent balloon observations by Dirk Muehlner and Rainer Weiss[3] of MIT also suggest too much flux in the 0.8–1.0 mm range.

Although the funding situation has limited the number of flights, groups at Cornell, NRL and Los Alamos are planning more rocket flights soon.

Last year Patrick Thaddeus (Institute for Space Studies), John Clauser and Victor Bortolot (Columbia University),[4] by measuring interstellar optical absorption lines of CN, CH and CH^+, established upper limits at three wavelengths on the intensity of background radiation in the interstellar medium. At 2.64 mm Thaddeus, Clauser and Bortolot measured a temperature of 2.8 K; they inferred upper limits to the background temperature of 4.7 K, 5.4 K and 8.1 K at 1.3 mm, 0.56 mm and 0.36 mm, respectively.

The limits are consistent with three-degree blackbody radiation. They imply a flux that cannot be reconciled with the rocket and balloon observations, say Thaddeus, Clauser and Bortolot, unless the flux being observed is concentrated into a sharp line that happens to avoid the molecular resonances, or unless the flux originates locally.

How could most of the radiant energy in the universe be produced in the form of lines? If the excess flux comes from quasars, distant galactic nuclei and the like, one would expect fairly broad-band radiation. The three-degree background radiation has 100 times the energy density of starlight throughout the universe. If the rocket and balloon observations are correct, the hypothesized line source would be 2000 times the energy density of starlight.

Recently Thaddeus and Philip Solomon (Institute for Space Studies) have been looking at interstellar formaldehyde, a very sensitive radiometer already located in outer space. The formaldehyde is cold—colder than 3 K, and it is apparently absorbing out the three-degree blackbody radiation. What could be pumping it down? Thaddeus and Solomon believe that the best explanation for the formaldehyde behavior is that there are small departures from the blackbody spectrum, about a degree or even a tenth of a degree, in the vicinity of 2 mm or less. They are extremely skeptical, however, that the departures are anything like the magnitude observed in rocket and balloon flights.

An alternative mechanism for the cooling of the formaldehyde, involving collisions between formaldehyde and hydrogen atoms or molecules has been proposed by Charles Townes and Albert Cheung (University of California, Berkeley).[5] —GBL

References

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CERN Proposes Missing Magnets And 150 GeV for New Machine

The CERN 300-GeV project, plagued with foot-dragging, international intrigue, and tight money, and most recently confronted with Robert Wilson's announcement that the Batavia accelerator might yield a 500-GeV beam by 1 July 1971, has announced a new design approach that might salvage the project. In mid-April the new proposal was presented for discussion to European governments and European scientists; a decision is hoped for by October.

In the initial 300-GeV concept, conventional combined-function magnets were arranged in a 2.4-km-diameter ring. The new proposal is for a "missing-magnet" design, in which only half the magnets are installed originally in a 1.8-km-diameter ring. (The Batavia accelerator originally had a "missing-power" design, allowing for a larger power supply to be installed later, so that energy could then be raised from 200 to 400 GeV. It later proved possible to get all the power required for 500 GeV at a cost low enough to install from the start.)

The CERN machine would start out with a maximum energy of 150 GeV but could have its energy doubled by doubling the number of magnets. If pulsed superconducting magnets continue to look as promising as they do now, the spaces could be filled with superconducting magnets, allowing a maximum energy of about 400 GeV.

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Then if the superconducting accelerator worked well, the whole ring could be filled with superconducting magnets, and the maximum energy could be about 800 GeV.

Because the new proposal calls for a smaller ring diameter the accelerator could be built across the road from the existing CERN-Meyrin site. The rock in which the machine tunnel would be bored is the same as has already proved satisfactory for the 28-GeV proton synchrotron and for the Intersecting Storage Rings, now nearing completion; CERN believes the site is suitable.

The advantages of the Meyrin site are at least twofold: The political de-