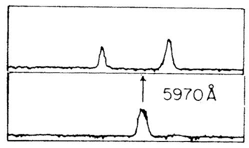
Physical Sciences

Lighting the way to bistability



Hillman/PRL

Conventional wisdom among laser physicists holds that lasers in one class, called homogeneous, operate at just one frequency no matter how great the power circulating in the cavity. Now researchers at the University of Rochester (N.Y.) have countered intuition by demonstrating otherwise.

Lloyd Hillman, now at Eastman Kodak in Rochester, Robert Boyd and co-workers showed with a rhodamine ring dye laser that the output splits from a single peak into two stable peaks (see figure) when the cavity power exceeds 85 watts. The peaks are separated by the so-called Rabi frequency—the frequency at which atoms are forced by the intense laser field to undergo transitions between energy levels. As reported in the April 30 PHYSICAL REVIEW LETTERS, the researchers found two regimes of this bistability. In each, the total output power of the laser doubled, the cause of which is as yet unknown.

While the onset of some sort of instability had been predicted in 1968, most physicists have either been unaware of the effect or thought it was too small or uncommon to be of concern. Instabilities in homogeneous lasers, says Hillman, are typically attributed to nonuniformities such as uneven heating or external mechanical vibrations. The recent experiment, he says, confirms that there is a change in the operation of the laser with increasing cavity power. This change is intrinsic to the way atoms interact with intense light and would occur regardless of how well the laser is built. The study also revealed the precise nature of the laser operation above the 85-watt threshold. Says Boyd: "We thought that the laser would simply go unstable; that the output would hop around in frequency and power in a random way. What we saw was surprising ... bistability in which the laser supported two frequencies simultaneously."

Defecting to gallium-arsenide

Of all the semiconductors challenging silicon's lofty position as the most commercially viable material for electronic devices, gallium-arsenide (GaAs) is the fastest emerging contender. Semiconductor companies, drawn to GaAs's promise of higher switching speeds, lower power consumption and greater radiation tolerance than silicon, are fiercely competing to develop GaAs devices for applications, especially those in which silicon falls short—in defense, space and supercomputers.

One of the hurdles to be overcome before GaAs carves out a niche in the market for integrated circuits is the growth of single crystals of GaAs that have few structural defects. Recently, Sumitomo Electric USA Inc. in New York announced it has grown crystals that have very few dislocations — a type of defect in which a plane of atoms is displaced from its usual position in the lattice. According to Sumitomo's Yasuhiro Nishida, the 65-millimeter-diameter crystal has between 0 to 200 dislocations per square centimeter — excluding a 2 mm region around the perimeter — the lowest density yet for crystals of this size that are close to commercial production. Conventional GaAs materials, he says, have densities on the order of 5,000/cm^2 at best, but tend towards 40,000/cm^2 in most commercial materials.

According to August Witt, a materials scientist at the Massachusetts Institute of Technology, the usual approach taken by researchers to decrease dislocations is to harden the material by adding an element like indium and to reduce the thermal stresses that cause dislocations when the crystal is growing. Nishida says that his company achieved the low defect density by improving the temperature gradient in the growth furnace. He would not comment on whether any hardening additive had been used. Sumitomo plans to reveal the details of its process, he says, at a GaAs integrated circuits conference this fall.

Cosmology

Dietrick E. Thomsen reports from the Inner Space/Outer Space meeting held at Fermilab in Batavia, Ill.

Antimatter?—Anti Theory?

If there were cosmology commercials on television, a feisty female senior citizen might be heard yelling: "Where's the antimatter?" Older cosmological theories need equal amounts of matter and antimatter in the universe, and their proponents worried because very little antimatter is found anywhere near us. The newer grand unified theories allow antimatter to decay into matter over long times, and so avoid the difficulty, even if the universe really started out 50-50.

It is known that there is little or no antimatter in our galaxy or in nearby ones, but somewhere there might be a cluster of antigalaxies, and some of their cosmic rays might reach us. (About one cosmic ray in 10,000 comes from outside our galaxy.) At the meeting, Stephen P. Ahlen of Indiana University in Bloomington, representing a group from Indiana University, the University of Michigan and the University of California at Berkeley, described a forthcoming experiment to seek antinuclei in cosmic rays. (Antiprotons, which do appear in the cosmic rays, don't satisfy. They can be produced by ordinary matter in flight.)

Ahlen described a detector to distinguish between, for example, iron and anti-iron. It will have a plastic scintillation counter that distinguishes between the positive charge of iron and the negative of anti-iron coupled to a Cherenkov counter that distinguishes their velocities. These pieces of information would identify anti-iron in the cosmic rays. A large detector of this type is planned for a two-day balloon flight.

A positive finding would mean that there is organized antimatter somewhere out there. A negative, Ahlen says, would be "the best evidence for grand unified theories." However, Gary Steigman of the Bartol Research Foundation in Newark, Del., disagrees, saying that a negative would not allow us to conclude there is *no* antimatter, and so support the grand unified theories' contention that primordial antimatter has by now decayed into ordinary matter.

Fractional charge redux

In an experiment running for more than a decade, William Fairbank of Stanford University and associates have been finding electric charge in fractions of the charge of the electron on little niobium balls (SN: 1/31/81, p. 68). Fractional charge is not supposed to exist, and if these *do* exist, they could be free quarks or some other exotica of cosmic importance.

Over the years, in their publications, Fairbank and his colleagues had progressed from "evidence for" fractional charge to "detection of." Now, Fairbank reports, they are stepping back to "evidence for." To measure the charge on the balls requires levitating them in a complicated combination of magnetic and electric fields. In some recent runs the balls behaved strangely, and it became clear that there was a torque on these balls that the experimenters hadn't appreciated. They wonder whether this torque affected earlier measurements, and that is why they are diluting their conclusion a little. However, they still believe there is fractional charge there, and they are refining the experiment to discount this new torque.

Starring Moffat theory

John W. Moffat of the University of Toronto has a theory of gravity to rival Einstein's general relativity (SN: 9/3/83, p. 152), and he collects instances of celestial behavior that seem to support his version. The latest concern two binary star systems. As two stars in a binary system revolve around each other, the major axis of their elliptical orbit usually swings around. However, in the case of the binary star Di Herculis no such precession of periastron has been found in 86 years. Moffat says his theory can explain this but Einstein's can't. He has also made a prediction for mu Scorpii, in which a negative precession has been observed. Observational friends of his, he says, are checking to see if the effects are there.

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