Achieving control of chaotic laser output

Irregular fluctuations in intensity have long plagued the operation of a wide variety of solid-state lasers. Present-day versions of these lasers owe their markedly improved stability and performance to a succession of engineering advances aimed at modifying designs or materials to circumvent such random behavior.

But that isn't the only way to proceed. Researchers are starting to explore the possibility of exploiting rather than avoiding a laser's chaotic output. As an important step in that direction, a group at the Georgia Institute of Technology in Atlanta has applied a novel control technique that automatically locks a solid-state laser's erratically fluctuating light into a regularly repeating pattern of intensities.

"It was very exciting to see we could control [the laser's output intensity] in this way," says physicist Rajarshi Roy, who led the Georgia Tech group. "We didn't know whether we could do it until we tried the experiment." Roy and his colleagues describe their results in a paper accepted for publication in PHYSICAL REVIEW LETTERS.

The researchers demonstrated their approach with a widely used type of solid-state laser made from a crystal of yttrium aluminum oxide laced with neodymium. The so-called Nd:YAG laser generates infrared radiation at a wavelength of 1,064 nanometers. Passing this radiation through a potassium titanyl phosphate crystal inside the laser cavity produces green light at half the original wavelength or double the frequency.

However, the use of a frequency-doubling crystal often induces random fluctuations in the laser's output of green light. Two years ago, Roy and his co-workers found they could eliminate this chaotic behavior and achieve stability simply by rotating the doubling crystal into certain positions.

"This was the unknown parameter that had varied from laser to laser when they were built in the past," Roy says. The discovery explained why some of these lasers showed chaotic behavior and others did not.

Reports last year of the development of a laboratory technique for dynamically stabilizing the chaotic vibrations of a magnetoelastic, metallic ribbon (SN: 1/26/91, p.60) prompted Roy and his group to consider a similar strategy for lasers. The trouble was that a laser's fluctuations typically occur far too rapidly for the kind of computer-mediated controls used in the ribbon experiments.

Roy found the solution in the work of Earle R. Hunt of Ohio University in Athens, who had developed a simple, high-speed, electronic method of converting rapid, chaotic voltage fluctuations in an electronic circuit into a periodic signal. "I realized this [electronic] hardware was exactly what we needed for our laser," Roy says.

To achieve control, Roy and his co-workers use a modified version of Hunt's circuitry to monitor the laser's output periodically and, in response, slightly alter the power output of the diode laser supplying energy to the Nd:YAG system. By applying minute, brief jolts at just the right rate, the researchers can turn a Nd:YAG laser's chaotic output into a periodic signal.

"Without the feedback, it's chaotic," Roy says. With feedback, the laser stays locked to a certain pattern for tens of minutes.

In addition, the researchers can readily shift the laser's output from one periodic pattern (or waveform) of intensity fluctuations to another. "With this control technique, you may eventually have the ability to generate different, complex waveforms in a laser system and to switch between these waveforms," Roy says.

"Right now, however, we're kind of at the trial-and-error stage," he adds. The Georgia Tech researchers would like to extend their technique to faster lasers and to develop electronic means of deliberately selecting and controlling the various waveforms emerging from a laser.

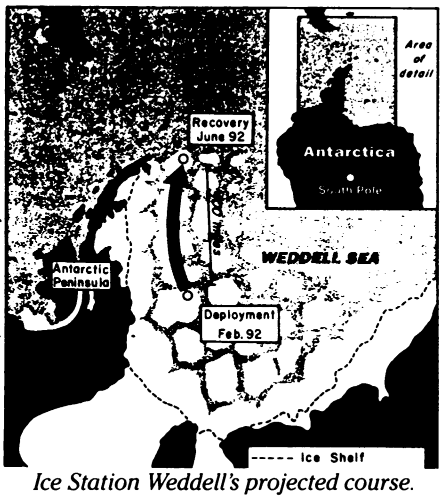
– I. Peterson

In Antarctica, scientists go with the floe

U.S. and Russian scientists launched the Antarctic's first floating laboratory last week. Built atop an ice floe nearly 2 miles long, 1 mile wide and 7 feet thick, Ice Station Weddell will carry 20 researchers on a 5-month, 400-mile journey through the western Weddell Sea — previously unexplored waters clogged year round by floating ice. Along the way, the scientists hope to learn more about how the region both influences and responds to global climate.

The 80 tons of equipment on the ice floe include instruments to measure the sea, ice and air. The expedition's primary goal is to study heat exchange between the ocean and the atmosphere and how the intervening ice influences that exchange.

"One of the largest uncertainties affecting the accuracy of models predicting the greenhouse effect is the role played by the ocean's sea-ice cover," says expedition member Douglas Martinson, an oceanographer with Columbia University's Lamont-Doherty Geological Observatory in Palisades, N.Y. "There is a surprisingly delicate balance between the atmosphere above the ice and the ocean below it. Consequently, relatively small changes in either atmosphere or ocean can lead to significant changes in the character of the Antarctic sea ice, which in turn can have a major impact on climate."



Ana Maria Alvarez/Lamont-Doherty

Ice Station Weddell's projected course.

Scientists also hope to learn more about the formation and dispersal of Antarctic bottom water, another Weddell Sea phenomenon that significantly affects global climate. Dense and frigid, Antarctic bottom water from the Weddell Sea surges northward into the world's oceans, drifting along 1,000 meters or more below the sea surface. "Antarctic bottom water is the refrigerator that makes the world's oceans cold," says Lamont-Doherty oceanographer Arnold L. Gordon, coordinator of the expedition's science programs.

Past measurements have indicated that bottom water in the southern Weddell is warmer than bottom water in the northern Weddell. Gordon speculates that the western edge of the sea somehow alters the bottom water as it flows northward. "We're not going to understand the whole story about the formation of Antarctic bottom water until we investigate that western rim," he told SCIENCE NEWS.

Since the greenhouse effect could alter the amount of Antarctic bottom water supplied to the world's oceans, expedition researchers will also try to determine the rate at which bottom water leaves the Weddell. "We really need to know: Is the Antarctic spigot going to become stronger or weaker as the climate changes under the greenhouse warming scenario?" Gordon explains.

Because of the large amount of equipment and the relatively small crew, experiments at Ice Station Weddell probably won't get into full swing until mid-March, Gordon says. However, with the station currently drifting northward at only 3 to 5 kilometers per day, the researchers shouldn't miss any important data, he adds. The expedition will end when the floe reaches warmer northern waters and begins to melt, sometime in June or July.

– M. Stroh