Physical Sciences

Light pipes for sensitive spectroscopy

Measuring the faint light emitted by a material confined within a massive, high-field magnet or in a refrigerator capable of attaining millikelvin temperatures is no simple matter. Often the probe necessary for collecting the data must snake through a tortuous access channel only a fraction of an inch wide. "A lot of science has been out of reach simply because of the difficulty of doing optical experiments in restricted environments," says Don Heiman of MIT's Francis Bitter National Magnet Laboratory. "It's like trying to look out of a peephole in your front door while standing in another room."

Heiman and his colleagues have solved the problem of access by using optical fibers as flexible pipes to carry light from confined samples to sophisticated spectrometers. Because these special silica fibers can transmit extremely weak optical signals amounting to less than one photon per second, researchers can detect a variety of subtle physical effects, even at temperatures as low as 50 millikelvins and in magnetic fields as high as 70 tesla. Researchers at MIT and a number of other laboratories now starting to use this optical-fiber technology have already discovered a number of novel optical effects in magnetic semiconductors and in fabricated structures known as quantum wells.

Squeezing the noise out of light

Quantum theory puts a fundamental limit on the precision with which a laser can generate light. This intrinsic randomness in the production of photons limits how much the noise, or fluctuations, in any signal can be lowered. Nevertheless, researchers have developed techniques for "squeezing" light, allowing them to reduce the uncertainty in one particular characteristic of a light wave at the expense of another, which becomes more random. By using the more predictable, or less noisy, component, they can improve the precision of a variety of optical measurements.

At this week's International Quantum Electronics Conference in Anaheim, Calif., several groups reported significant advances in squeezing light. In particular, Prem Kumar and his colleagues at Northwestern University in Evanston, Ill., have reduced the amount of noise caused by the random emission of photons by a record 75 percent. "To our knowledge, this is the highest quantum noise reduction ever observed in any experiment to date," the researchers say. Their method involves splitting pulsed laser light into twin beams and measuring the number or location of photons in one beam, thereby gaining information about the photons in the unaffected twin (SN: 3/10/90, p.151).

Interstellar graphite in meteorites

In their continuing search for interstellar "needles" in the meteoritic "haystack," Edward Anders of the University of Chicago and his collaborators have identified tiny grains of graphite, 1 to 4 microns in diameter, in a meteorite known as the Murchison C2 chondrite. Their report appears in the May 17 NATURE. Anders and others had previously reported finding microscopic diamonds and silicon-carbide grains in a number of meteorites (SN: 3/14/87, p.166; 2/7/88, p.7).

Using as evidence the measured ratios of the isotopes carbon-12 and carbon-13 in the graphite grains, the researchers argue that the graphite may have formed in the outflows from carbon-rich, red-giant stars or in the envelope of matter abruptly expelled when a star rapidly brightens to become a nova. Deposited as particles in interstellar space, the graphite could then be swept up in the processes leading to the formation of a meteorite. It remains unclear, however, why graphite is much less abundant than diamond, which should be less stable, in the same meteorite.

Space Sciences

An unexpected solar effect on Venus

Pioneer Venus, a spacecraft that has orbited Venus for more than 11 years, revealed early in its mission that the number of free electrons in the planet's ionosphere often varies from one orbit to the next. The reason for this phenomenon, however, appears different from what scientists have assumed.

According to Larry H. Brace of NASA's Goddard Space Flight Center in Greenbelt, Md., two kinds of solar variations may affect the number of electrons in Venus' ionosphere: the sun's extreme ultraviolet (EUV) brightness, and the speed and density of the solar wind. Many researchers working on the problem have assumed that the number of electrons in Venus' ionosphere rises and falls with the amount of solar EUV light, which can free electrons by ionizing neutral atoms in Venus' sun-facing upper atmosphere. However, Brace and his colleagues report in the recently released April 1 JOURNAL OF GEOPHYSICAL RESEARCH that the density of the solar wind appears to influence the up-and-down electron population measured by Pioneer Venus to a far greater extent than does the sun's EUV. Sometimes, the authors suggest, the solar wind just transports the electrons around to the planet's night side. But on other occasions, when the solar wind contains a greater number of charged particles, it may "blow" the electrons completely past the ionosphere and into space.

Most of the difference in the number of Venus ionospheric electrons shows up in the "ionotail," a term Brace coined in 1987 to describe the portion of the ionosphere that the solar wind pushes out into space so that it resembles the tail of a comet. Unfortunately, even the 11 years' worth of data gathered by Pioneer Venus have not provided enough evidence to show conclusively what makes the number of electrons change.

But the craft has shown that the height of Venus' ionosphere apparently depends on the sun's cycle of energy output, which averages about 11 years. Data gathered near a time of minimum solar activity revealed very large changes in the number of electrons detected well down the ionotail, about 1,400 to 2,500 kilometers from Venus. However, Brace says, near solar minimum the variations in the sun's EUV output are small and their effect on electron production is difficult to judge.

Some measurements made at solar maximum showed that the sun was radiating less EUV light at that time and that Venus' ionosphere was lower, with the craft encountering electrons only 150 to 600 km above the planet. This time, the data showed that with the sun's EUV output varying widely, the number of electrons went up and down only a little.

As for the solar cycle's peak, "we don't have sufficient data for solar maximum yet," says Brace. "But we have enough data at times of moderate solar activity — on either side of minimum — to see that the ionosphere's electron densities do follow the solar-cycle variations." Brace's group is now looking at the craft's data for signs that some free electrons are being accelerated enough by the solar wind to leave the ionosphere.

Still seeking a Martian magnetic field

Scientists have long tried to determine whether Mars has its own internal magnetic field or if the solar wind's magnetic field lines simply wrap around the planet. Now, using data from the Soviet Union's Phobos 2 spacecraft, a group of researchers that includes Janet G. Luhmann and Christopher T. Russell of the University of California, Los Angeles, has observed that the magnetic "tail" streaming out from Mars looks as it should if it were due to the solar wind. An internal field would be produced by a dynamo effect produced within Mars' core.

"Unless there's an exotic dynamo the likes of which we've never seen before, Mars has none at all," says Russell. The group plans to report its finding May 30 at the American Geophysical Union meeting in Baltimore.