blobs of gas falling toward the star at several hundred kilometers per second. The simplest explanation, says Sara Heap of Goddard, who has studied the Beta Pictoris system, is that the observed spectral lines come from gas that evaporates from solid bodies plunging toward the star in near free fall, most likely comets.

Infalling comets can also explain another feature of the GHRS data: the ultraviolet signature of carbon monoxide and neutral carbon in the star's dust cloud. Radiation from the star should quickly destroy these relatively fragile species, Lagrange says. But comets could be replenishing the supply by ferrying gas and dust inward from the far reaches of the disk, she says. Together, the evidence suggests that as many as a few hundred comets a year plunge toward this young star, says Lagrange, probably about the same number as in the early days of our own solar system.

Aurora on Ganymede

Just last summer, planetary scientists learned that the Jovian moon Ganymede has two planetlike features: a magnetic field and perhaps a trace of an atmosphere (*Science*, 19 July, pp. 311 and 341). Now, with the help of the GHRS, they may have found a third, the offspring of the first two. Astrophysicist Doyle Hall of Johns Hopkins University in Baltimore and his colleagues have detected hints of an aurora at Ganymede's poles.

The aurora—ultraviolet emissions from high-energy oxygen molecules—is a ghost of the powerful auroras on Earth and Jupiter, but it is the first to be seen on a moon, Hall says. And it is presumably generated by the same basic mechanism as planetary auroras: Magnetic field lines funnel high-energy electrons and other charged particles from space into Ganymede's polar regions, where they collide with gas molecules and excite them into giving off radiation.

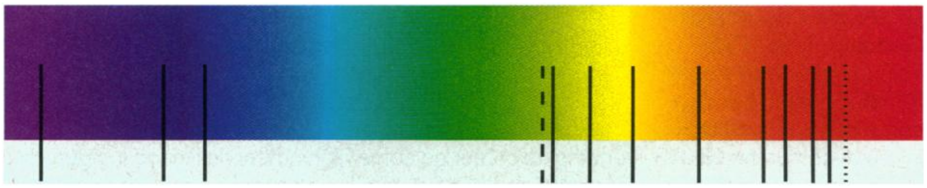
The emissions from Ganymede's aurora are so faint that they eluded Galileo, the spacecraft that swooped by Ganymede last summer and detected its magnetic field. "We had the luxury of parking the [Hubble telescope] on Ganymede for five full orbits," says Hall, giving the scientists time to pick up very faint signals. "Galileo just doesn't have that kind of time as it swings by."

Hall cautions that definitive proof of the aurora will require an actual image of the moon rather than just spectrographic data. But John Clarke of the University of Michigan, who studies Jupiter's aurora, calls the find "potentially exciting." He says that comparisons with Ganymede might give scientists a sharper picture of the interactions that give rise to Earth's aurora. "It will be interesting if we have a case that is different from Earth, but not entirely different," he says.

–**Gretchen Vogel**

MATERIALS SCIENCE

Plastics May Add New Colors To Lasers' Light Show



A. HEEGER, R. FRIEND, V. VARDENY

Across the rainbow. Work done by three teams (shown in solid, dashed, and dotted lines) shows that plastic polymers can emit laserlike light in colors all along the visible spectrum.

Lasers are one of this century's shining technological success stories, having metamorphosed from the ungainly machines of the 1960s to the ubiquitous crystals that today help electronic devices play music, read computer discs, and scan grocery labels. But although the semiconductor alloys in the laser diodes of CD-ROM drives and compact-disc players can turn out red and infrared beams with ease, researchers have had a tougher time coercing these inorganic materials to emit rays of yellow, green, or blue light—colors that could boost the amount of data stored on a compact disc, for example.

In recent weeks, however, a trio of research groups has produced laserlike beams from a new and potentially more versatile source—a variety of plastic films. Their results are sparking new excitement in the laser community. The new reports are "very nice work," says Francis Garnier, a semiconducting polymer expert at France's Centre National de la Recherche Scientifique in Thiais. If this basic research does lead to practical polymer lasers, the new materials would have an advantage over their inorganic counterparts, says Garnier, because "you can play with polymers much more easily than with inorganic semiconductors to create the colors you want." Indeed, on page 1833 of this issue, one team, led by researchers at the University of California, Santa Barbara (UCSB), already reports coaxing light in colors across much of the visible spectrum from these skinny bits of plastic.

But Garnier and others quickly point out that polymers have a long way to go to fulfill such brilliant dreams. At this point, the beams coming from these experimental plastic films don't show all the hallmarks of true laser light. And in all three experiments, the plastics emitted laserlike light only after being blasted by light from another laser. To become commercially useful, the devices will need to perform when powered by electric current, a difficult task because the polymers burn out quickly and are inefficient at turning electrical charges into light, says Richard Friend, a physicist at Cambridge University in the United Kingdom and leader of the second research team. Nevertheless, many researchers remain cautiously optimistic. "I'm full of promise and upbeat" that such problems will be solved, says Valy Z. Vardeny, a physicist at the University of Utah, Salt Lake City, who led the third team. After all, he says, "this is only the beginning of the story."

At the heart of the plastic light-emitters is a class of materials known as semiconducting polymers, which, unlike most plastics, are able to conduct electricity. In 1990, Friend and his Cambridge colleagues showed that these materials could also emit a yellow-green glow when pumped with electricity, creating devices known as light-emitting diodes (LEDs). Not long after, researchers created other polymer LEDs that gave off a range of different colors. The obvious next step was to try to turn these versatile light-emitters into lasers. That's a tough job, however, because it requires coaxing the plastics to first emit and then to amplify light of a single wavelength, with the waves all exactly in step; these traits give lasers their precision and intensity.

Lasers achieve this singular behavior because each photon emitted by the material stimulates the release of another photon, at the same wavelength as the first and exactly in phase with it. In a true laser, a chain reaction ensues, and this cascade of stimulated emission generates an intense pulse of light at a single wavelength.

But although early experiments with semiconducting polymer films did reveal some stimulated emission, the materials didn't actually lase, because the chain reaction that prompts the light to emerge at one wavelength never got started, explains Alan Heeger, who led the UCSB group. Preliminary work suggested that the films tended to lose energy to heat rather than emitting it as light, a fault known as poor "luminescence efficiency." And other work indicated that most of the photons that were produced were simply reabsorbed rather than emitted.

But a trickle of experiments continued to hold out hope, says Friend. For one, in 1992, UCSB physicist Daniel Moses showed that semiconducting polymers in a dilute solution could be coerced to emit laser light. And over the next few years, several groups demonstrated that thin films of common semiconducting polymers did indeed show high luminescence efficiency when blasted by laser light. "Once you get a high luminescence-efficiency material, it ought to lase," says Friend.

Only the reabsorption of photons was preventing true lasing in the polymers, it seemed. Impurities or defects in the films appeared to be at fault, says Heeger, so in this round all three groups were careful to limit such impurities.

That care seems to have paid off, and in late July all three groups presented evidence of success at a conference in Snowbird, Utah. Each team fired strong beams of laser light at their polymer films and were rewarded by light emerging from the polymers at a specific wavelength. While the Cambridge and Utah groups each showed this effect for a single polymeric material, the California group demonstrated the phenomenon in more than a dozen different semiconducting polymers or polymer blends. Each material gave off a different wavelength of light, showing that in principle at least, polymer lasers can cover much of the visible spectrum, including yellow and blue—colors with which conventional diode lasers have trouble (see figure).

The ability to emit light at just one wavelength, however, is just one criterion of a true laser. The waves also have to travel in step, and this "coherent" light has to form a single beam. At this point, none of the three groups has quite met all these goals. But the Cambridge group, which published their results in the 22 August issue of *Nature*, has demonstrated all but coherence, and at this point that is likely just a formality, says Heeger. Friend and his co-workers went the extra step by placing their polymer film inside a tiny device known as a microcavity, which contains a pair of mirrors that bounce the photons back and forth through the lasing material, coaxing the material to emit more and more photons in the same phase and shaping the emitted photons into a directed beam. Placing the other polymers in similar devices should yield similarly improved performance, says Heeger.

Although that's likely to be an easy step, most laser experts agree that the real goal of making electrically powered polymer lasers is further away. One big problem is the amount of energy needed to kindle current plastic light-emitters. To match the intense laser light now used to deliver that energy, electrically powered devices would have to shoot thousands of amperes of current into the thin polymer films in a fraction of a second. That task, says Garnier, "would be absolutely incompatible with current electrode designs."

And thanks to quirks of quantum mechanics, semiconducting polymers are far more likely to emit light when pumped with photons of light rather than with electrical charges, notes Utah's Vardeny. When electrically pumped, at least three-quarters of the charges end up generating not light but heat, which may cause the device to burn out quickly.

Can semiconducting polymers meet all these challenges to make commercially viable plastic lasers? Given these latest results, "it's definitely possible," says Garnier. But, he adds, it will require new materials that convert electrical charges to light more easily and can withstand high temperatures. Until such materials are developed, practical polymer lasers are likely to remain a bright light on a distant horizon.

–Robert F. Service

NEUROBIOLOGY

How the Songbird Makes His Song

In human organizations, those at the top tend to set strategy while leaving the details to their underlings. The same thing seems to happen in the brain—at least in the brain of the male zebra finch as it controls the bird's singing. On page 1871, Albert Yu and Daniel Margoliash of the University of Chicago provide the most detailed look yet at how the finch's brain controls the bird's singing muscles, and they find a chain of command that might be familiar to any management-school graduate.

The work shows, Margoliash says, that the singing instructions are relayed down a hierarchy of brain regions, getting progressively more detailed as they go. The firing patterns of the neurons in the higher brain centers apparently specify the more complex components of the birds' songs, the syllables, which are collections of notes, while the patterns at the lower level in this neural chain of command define the basic sounds—most likely, the notes themselves.

While neuroscientists have long suspected that the brain has such hierarchical motor programs, there was little direct evidence for the hierarchy. This report "is something that people have been looking for," comments neuroscientist Eric Vu of the Barrow Neurological Institute in Phoenix, whose own earlier work on zebra finches had hinted at a similar result. "It shows that to perform more complex behavior, the brain follows a chain of command: Higher brain centers are responsible for more abstract [information], and lower brain centers fill out the details." As they traced this hierarchy, Yu and Margoliash also found additional support for the idea that the timing of the impulses from a nerve cell, not just the number of pulses in a given period of time, carries information (*Science*, 3 November 1995, p. 756).

BENJAMIN C. YU

Singing for science. Lightweight headgear, including implanted electrodes, doesn't stop his song.

The findings may also help neuroscientists understand speech production in humans, because human speech, like bird song, is modular. Whereas a song consists of notes strung together in syllables and then phrases, human speech consists of phonemes, basic utterances such as the sounds associated with particular letters, linked together in words, which then form sentences and paragraphs. If the firing patterns of neurons in different brain regions define the finch's notes and syllables, then some similar organization may be at work in the human brain's speech production centers, Margoliash and others suggest.

Until now, the most direct evidence suggesting hierarchical control of bird song came from work done in 1994 by Vu's team. At the time, other researchers had already implicated several regions in controlling bird song. Vu, and subsequently Margoliash and Yu, studied two of them: the HVc, a cluster of nerve cells sometimes called the song production center, and the robustus archistriatalis, which relays input from the HVc down toward the base of the brain, where the RA's nerve cells interface with those that activate the right muscles for making sounds.

For his study, Vu implanted tiny electrodes in either the HVc or the RA of various zebra finches and observed how sending an