bate during a recent conference, in which some astronomers mentioned that standard models have difficulty making a planet of even Jupiter's size before the planet-forming disk dissipates. And if Jupiter did not form by agglomeration in a disk, said the astronomers, then strictly speaking it should not be called a planet. Says Wetherill, "I can just see the headline: 'Scientists Find That Jupiter Is Not a Planet.' "

He thinks theorists will find ways to create the full range of otherworldly planets, no matter how massive or eccentric. Some of the latest developments seem to support this view. Computer models by Stockholm's Artymowicz and Lubow, of the Space Telescope Science Institute, have shown that the growth-limiting gap that opens in the disk may have "weak points," allowing streams of gas to leak through and continue feeding a protoplanet. "It would allow a mechanism by which planets can grow larger" than theorists had thought possible, says Michigan's Adams. "To me, the idea has a lot of plain appeal; it makes sense."

The dynamics of the planetary disk could also allow some planets to be born in eccentric orbits, Artymowicz and Lubow have found. The team points out that a growing planet excites spiral waves in the disk that serves as its nursery—analogs to waves studied by Goldreich and Tremaine in Saturn's rings. Interactions with those waves can drive a planet's eccentricity either up or down, the team found. The waves affect planets differently depending on their mass, with planets smaller than 10 Jupiters losing eccentricity and heavier ones gaining it, roughly the pattern seen in extrasolar planets.

Even making giant planets close to their parent stars—rather than forming them elsewhere and transporting them inward—may not be unthinkable. "It may be possible. That's all I can say," notes Lissauer, who has done preliminary work on the possibility with Olenka Hubickyj, also at Ames, and UCSC's Bodenheimer. Going slightly further, Bodenheimer notes that JPL's Ward has proposed that material draining inward from the disk might supply enough mass to build a giant planet in a region that had been reserved for mere Mercurys.

Just as biologists have realized that bears—or human beings, for that matter—are by no means a necessary end point of evolution, astronomers are realizing that our own solar system is not the inevitable result of planet formation. As their surprise fades, observers are left searching the tangled bank of the heavens for more clues to how it all came to be that way.

–James Glanz

Additional Reading

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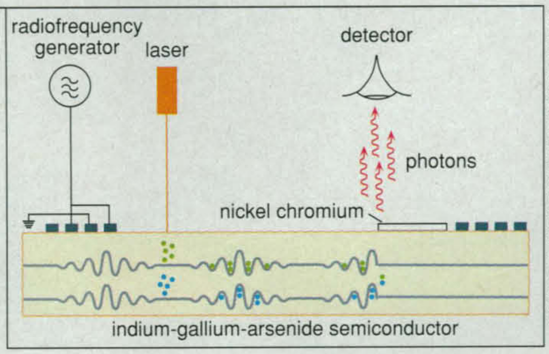
OPTOELECTRONICS

Storing Light by Surfing on Silicon

Light is a great way to transmit information, but its speedy photons are difficult to slow down when signals must be delayed—for example, to be stored for brief times in optoelectronic circuits. Now a report in the 26 May *Physical Review Letters* describes a clever solution: translating photons into pairs of electric charges that slowly "surf" on a sound wave across a semiconductor chip until they recombine in a pulse of light.

The traditional way to delay an optical signal is to send it racing through loops of optical fiber several kilometers long—a bulky and expensive solution. Physicists at the University of Munich and the Technical University of Munich suspected they could do better. The team members began with a 10-nanometer-thick slice of an indium-gallium-arsenide semiconductor, a material that can translate light into electric charge and vice versa. The team sent an optical signal into one end of the chip by pulsing a laser onto its surface. The laser's photons created excitons: wandering pairs of electrons and the positively charged "holes" from which the electrons have been dislodged. Normally these excitons would recombine, giving off light again, within a nanosecond (a billionth of a second). But a second property of the material allowed the team to delay their reunion.

Indium-gallium-arsenide has piezoelectric properties, meaning that its electrical properties change if the material is stressed. The reverse is also true: The material extends or shrinks when an electric field is applied. By connecting a radio-frequency generator to a series of strips along one edge of the semiconductor, the group set up compressional waves—sound waves—that swept across the chip. Along the way, the sound altered the electric field in the semiconductor, creating electric-field waves that separated the electrons and holes, preventing them from recombining. "We can extend the lifetime of the excitons several orders of magnitude," says Achim Wixforth of the University of Munich.



Sound system. Excitons—electrons (green) and "holes" (blue)—are separated by sound wave traveling left to right in an ultrathin semiconductor layer. Photons are produced when the excitons recombine.

The excitons survive until the migrating electrical fields drag them all the way across the chip. At the far end, the field wave breaks down when it reaches a nickel-chromium strip, and the excitons merge, emitting a flash of light.* In the experiment, the team detected a light pulse from recombining excitons 650 nanoseconds after they were created by a laser pulse. That may not sound like much, but an equivalent fiber-optic delay would require about 3 kilometers of cable, says Wixforth.

Wixforth notes that, instead of using a metallic strip to break down the electric-field waves, the team can control the release of the "stored" photons by sending a second sound wave into the chip in the opposite direction from the first one. The electrons and holes recombine at the point where the two waves meet. "We can thus switch off the storage of light signals at any time," says Wixforth.

The device isn't ready for commercial use just yet. At present, the chip must be cooled to within a few degrees of absolute zero, but team member Carsten Rocke of the University of Munich says less chilly chips are on their way. After that hurdle is cleared, the team predicts that the chips could become an integral part of optical systems. Other physicists agree: "Whatever you can do with a delay line, you can do with this, too," says David Snoke of the University of Pittsburgh.

–Alexander Hellemans

*An animation of the process can be viewed at: www.aip.org/physnews/graphics

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