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WHAT'S NEXT

Quantum Theory Could Expand the Limits of Computer Chips

By ANNE EISENBERG

Using principles of quantum theory to manipulate light is the stuff of rarefied research, not the factory floor. But quantum theory may turn out to have surprisingly practical applications in manufacturing faster computer chips.

That is because most microchips are made by optical lithography, a process that uses light to carve the circuits that are etched on chips. The shorter the wavelength of this light, the finer the paths that can be created and the sh the time electrons need to travel through a circuit. The result is a faster chip.

But a rule of classical optics limits the size of the paths to about half the wavelength of th used to etch them. Beyond that, the light can't be focused precisely enough to write struc like transistors on the chip. And manufacturing techniques are beginning to approach that

Now researchers have shown that they can get around this rule of classical optics by usin different set of rules: those of quantum mechanics. Led by Dr. Yanhua Shih, a physicist a University of Maryland at Baltimore, a team of scientists has experimentally verified a w focus light to far less than half its wavelength. The technique could lead to smaller, faster without the need to change the basic manufacturing processes of lithography.

The University of Maryland group described the experiment in the journal Physical Review Letters in September. In the experiment, they forced individual particles of light, called photons, into pairs.

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Photons usually exist singly and do not interact with one another. But in these special quantum states of light, the paired photons behave in ways that are so highly connected that physicists describe them as "entangled." It is these entangled pairs that were used to exceed the classical wavelength limit.

Dr. Shih's work follows a theoretical paper published in June 2000 in Physical Review Letters proposing that entangled pairs of photons be used to focus light to regions smaller than those achievable by individual photons, thus making them useful in lithographic processes.

Dr. Jonathan Dowling, a physicist at NASA's Jet Propulsion Laboratory at the California Institute of Technology in Pasadena, Calif., and one of the authors of the theoretical paper, said he was very relieved to read Dr. Shih's results. "I'm a theorist," Dr. Dowling said, "so when I predict an effect that hasn't been seen, there's always a nagging doubt that it won't agree with the experimental data. This is the first proof that the prediction is legitimate."

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The Shih paper is important, Dr. Dowling said, because "if we can halve the space betwe features on chips, we can put twice as many features in the X dimension and twice as ma the Y dimension." This might mean that four times as many circuits might be placed on a

Entangled photons like the ones used by Dr. Shih's group could be produced in a laborato passing a light beam through a special crystal, and in other ways. In the Shih experiment, entangled photons were created by shining an argon laser beam through the crystal.

Dr. Daniel Gauthier, a physics professor at Duke University, explained the method, whicl has used in his lab. "This is one of the many nonlinear methods known to produce quantu states of light," he said. "You take one blue photon, annihilate it in the crystal, and it gene two near-infrared photons."

Once the photon pairs are created, they act quite differently from single photons, behavin ways that are closely connected. In the Shih experiment, the paired photons were forced t small apertures, creating a pattern of light and dark fringes. The distribution of the entang photons in this pattern was measured with highly sensitive photodetectors that registered virtually simultaneous arrival. The researchers showed that the distance between the brig dark fringes of light was half what would occur with ordinary light. Thus the entangled p promise twice the resolving power of ordinary photons.

Quantum theory explains this, in part, on the basis of an idea first proposed by Louis de E that particles share some properties with waves. One similarity is that their wavelength is inversely proportional to their momentum. Here the pair of entangled photons has twice t momentum of a single photon and hence half the wavelength, giving the paired photons c the power of a single photon to focus feature size.

"This work certainly shows that the basic physics is right," said Dr. Carlos Stroud, a prof optics at the University of Rochester and the director of the Center for Quantum Informat "There's no question that they've demonstrated the basic effect."

That doesn't mean, though, that the technique will be showing up any time soon in an Int (news/quote) factory. The current sources of entangled photons are not as intense as they need to be, for instance, to project a circuit pattern on a photoresistive layer, as would be necessary in lithography.

"Mother Nature never gives you something for nothing," said Dr. Alexander Sergienko, a physics professor at Boston University who also works with two-photon effects. "These p more flexible, but there are fewer of them."

Equally important, said Dr. Dowling, is the development of a suitable material for the photoresistive layer, one that could convert the special properties of two-photon light into on a wafer. The experiment done by Dr. Shih did not actually project a circuit pattern on photoresist - the researchers imitated the process using photodetectors that registered the photons electronically, as no material capable of absorbing the simultaneous arrival of th photons yet exists, Dr. Dowling said.

"It's basically a chemistry problem," Dr. Dowling said. "The critical thing, and where we putting our efforts, is in finding a material for the substrate."

Right now, the prospect of quantum lithography is still "a bit pie in the sky," Dr. Gauthie "But only for technical reasons," he added, saying such delays were normal. "What's nea that they've shown a way to get beyond traditional limitations in lithography."