PHYSICS:

Yoked Photons Break the Light Barrier

Charles Seife

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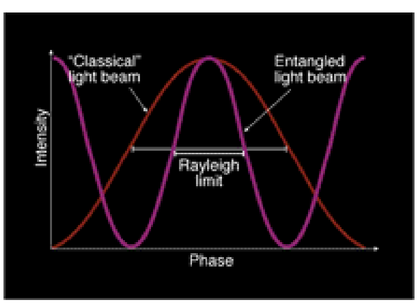
It seems to flout the laws of physics, but scientists have found a loophole in the rules that govern diffraction. By exploiting entanglement, the quintessential "spooky" phenomenon in quantum mechanics, physicists at the Jet Propulsion Laboratory in Pasadena, California, have come up with a method for drawing tiny features on a microchip that would be impossible according to the classical theory of light. If it proves practical (always a big "if" where quantum effects are concerned), the technique--described in the 25 September issue of *Physical Review Letters*--could enable chip designers to circumvent the so-called Rayleigh limit, a physical barrier that plagues chip manufacturers much as the sound barrier used to bedevil aerospace engineers. As team member Jonathan Dowling puts it, "Murphy's Law has been repealed, at least in theory."

If so, the reprieve comes in the nick of time. Although computer chips are growing ever smaller and more powerful--doubling in speed and halving in cost every 18 months or so--it's getting harder and harder to manufacture those chips. One reason is that most chips are made by photolithography, a process in which the manufacturer shines light through a patterned "mask" onto a chip slathered with a light-sensitive coating called photoresist. The light toughens the coating, allowing the manufacturer to etch away unexposed parts of the chip.



Sharper image. By halving photons' effective wavelengths, quantum entanglement may enable chipmakers to etch much smaller transistors.

Unfortunately, as microcircuitry grows ever finer, chipmakers run smack into the Rayleigh limit, which dictates that the smallest feature a light beam can write on a chip is half the wavelength of the light. To etch smaller and smaller transistors, manufacturers must resort to shorter and shorter wavelengths--moving from red to blue to ultraviolet to extreme ultraviolet to x-rays. Short wavelengths, however, are both hard to control and tough on chips. The Rayleigh limit ensures that manufacturers pay dearly for smaller transistors.

To smash the barrier, Dowling and colleagues imagine "entangling" two photons so that when they are shot at a beam splitter from opposite directions, they will always wind up moving together in lockstep. Thus yoked, the photons will remain inseparable until they strike a target--in this case, the chip-in-progress. "This strange quantum-mechanical disembodiment allows them to conspire to arrive at the same atom at the same time," Dowling says.

If the entangled photons are made out of red light, the optics will bend them just as they bend red light, Dowling says. But when the two photons hit the target together, their combined energy might equal that of a single ultraviolet photon--a particle with a shorter wavelength. "It acts like UV for all intents and purposes," says Dowling. In fact, if you set up an interferometer, the interference pattern would look like one for ultraviolet photons rather than red ones: The fringes are twice as fine. That should make it possible to etch transistors twice as finely as the Rayleigh limit allows, Dowling says, provided that chipmakers can find photoresist that still hardens well when struck by photons with twice the usual angular momentum.

"Dowling had a very brilliant idea to use this for lithography," says Yan-hua Shih, an experimentalist at the University of Maryland, Baltimore County, who is trying to put the scheme into effect. Photoresist is his current stumbling block, he says. "Two-photon absorbing materials are not very sensitive; we’re looking for a much better material."

Other scientists, however, think it will take more than tinkering to rout Rayleigh. Paul Kwiat, a physicist at Los Alamos National Laboratory in New Mexico, suspects that the difficulty of creating bright beams of entangled light will limit the usefulness of the technique. "But it’s good to have people think about these things," he adds.

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