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physics : Fine lines

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Manufacturers of silicon chips attempt to 'paint' the finest of lines, because making chips more powerful means making their components and connections smaller. The smallest wires that can be 'written' into most chips are currently just under 200 millionths of a millimetre wide. The semiconductor industry wants to go smaller than this, but is constrained by a fundamental principle of physics.

Now researchers from the USA and the UK propose that this limit can be overcome using peculiarities of quantum mechanics -- which reaches parts that 'classical' physics cannot.

Making a circuit pattern from a flat semiconductor or metal film is actually more like sculpture than like painting. The circuit is typically 'engraved' by dissolving unwanted material with etching agents such as strong acids; a robust polymer coating protects the desired circuit shape.

In one common form of this process, the molecules that link to make the polymer are coated on the semiconductor surface, which is then flooded with light through a mask. Light stimulates exposed molecules to join and the rest remain as 'loose' molecules, which are subsequently washed away.

This procedure, called photolithography has served the microelectronics industry well for decades, but it is now facing a brick wall. The mask can only cast 'shadows' as thin as the light wavelength allows: roughly speaking, it is impossible to imprint a feature smaller than half a wavelength. Going below that is like trying to paint a miniature with a fat brush.

For visible light (wavelengths of 400-700 nanometres), this sets the sculpture limit at about 200 nanometres. In fact, for technical reasons laser-generated ultraviolet light of just 248-nanometre wavelength is needed to make state-of-the-art 180-nanometre features

But for more powerful computers, chip manufacturers will need to push this feature size down to 100 nanometres (0.1 micrometres) at least -- this 'Point One' is something of an industry Holy Grail. Features this small can in principle be made with other emerging lithographic techniques, which use very short wavelength ultraviolet light, X-rays or beams of high-energy electrons or ions. But there are many practical obstacles to their commercial development.

Yet Point One is already within reach, Jonathan Dowling of the California Institute of Technology, Pasadena and colleagues now claim -- provided that you do something strange with light.

The group uses a quantum-mechanical effect called 'entanglement', which can be induced in light photons, the individual 'particles' or energy packets of a light beam. Entangled photon pairs have enmeshed fates: if something is done to one of them, it affects the other instantly, no matter how far away it is. This strange 'action at a distance' is a property seen only in the world of quantum physics.

As Dowling's team reports in *Physical Review Letters*[1], if two entangled photons are recombined by bouncing them towards one another, they act like a single photon with half the wavelength.

In principle, such light could then 'write' features four times smaller than can normal light. And entangling three photons (which is much harder) would reduce their 'effective' wavelength to one-third of the 'real' one, so engraved features could be nine times smaller.

Whether the semiconductor industry will turn to quantum physics to maintain their incredible shrinking act remains to be seen. But the work shows that a little ingenuity may at least stave off the industry's need to reinvent itself.

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1. Boto, A. N. *et al.* Quantum interferometric optical lithography: exploiting entanglement to beat the diffraction limit. *Physical Review Letters* **85,** 2733-2736 (2000).