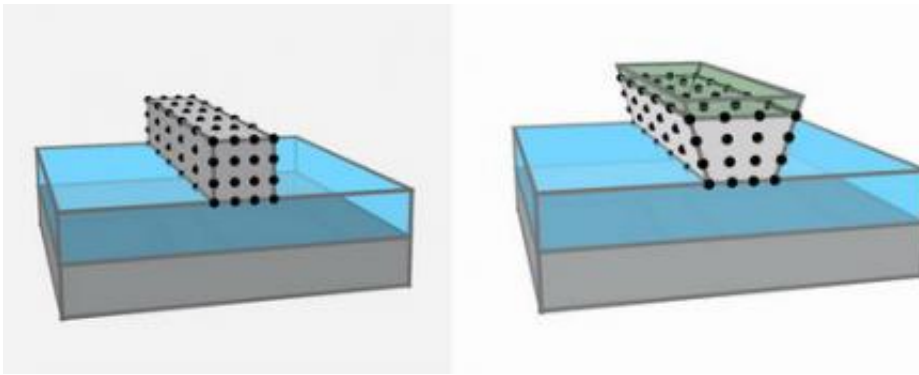


# Strained silicon carries light for cheaper commercial electronics

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The silicon waveguide at left contains a crystal symmetry and no electro-optic effect. At right, the silicon waveguide has a straining layer that breaks the symmetry. The broken symmetry makes it possible to change the phase of light by applying an electric field across the waveguide, which can create an electro-optic modulator. Photo credit: Rune Jacobsen.

By physically compressing a silicon waveguide – and thus allowing variations in the way light travels through the material – scientists have discovered a key to creating a silicon electro-optic modulator. This method could greatly decrease the cost of modern computers.

“Inside your computer, there are a bunch of small black components,” explains Rune Jacobsen, coauthor of a recent paper in *Nature* on strained silicon. “There is a silicon die inside each component, and it is in these chunks of silicon where all the ‘magic’ happens.”

Silicon, considered the material of choice in electronics for decades, now has one more reason to be at the top. Scientists have observed electro-optical effects in silicon, which is the ability to convert electronic signals into optical signals. Previously silicon was thought to have limited optical properties due to its strong symmetrical traits and lack of an electro-optic coefficient.

“We discovered a method that induces an electro-optic effect in silicon, which is done by deposition of a straining layer on top of the silicon crystal,” says Jacobsen. “The straining expands, and hence it deforms, the crystal structure of the silicon underneath [see figure]. This is not difficult, but until we made the discovery, it was not realized that you could make silicon electro-optically active by breaking the crystal symmetry.”

The straining layer, composed of silicon nitride glass, compresses the silicon waveguide, a structure that guides light waves in the silicon. Using this straining method to break silicon’s crystal symmetry, the team has realized the possibility of using silicon to modulate a beam of light.

The glass straining layer acts purely as a physical strain, asymmetrically compressing the silicon waveguide so that the waveguide expands horizontally. This physical change enables silicon’s bulk refractive index to vary linearly under the influence of an external applied electric field, creating electro-optic effects.

“The index change is caused by a perturbation of the electron orbitals, which is the fastest physical process possible at room temperature,” says Jacobsen. “The time constant is typically lower than  $10^{-15}$  seconds; i.e. the effect can be as fast as 1,000,000 GHz.”

Another way to put it is that the electric field can slow the velocity of light waves in silicon due to the material’s broken symmetry. Once

applied, the electric field can instantaneously determine whether or not light travels through a silicon modulator.

“Such an electro-optic modulator is typically used when transmitting data, where transmitted light corresponds to a ‘1’ bit and no light to a ‘0’ bit,” wrote the scientists.

This design differs from previous demonstrations of silicon modulators, which have used an electric current traveling through the silicon to achieve modulation.

“In our demonstration, we use an electric field to achieve modulation instead of electric current,” says Jacobsen. “In 1987, Richard Soref et al. showed that you can make a modulator by leading an electrical current through the silicon and then changing the size of the current (ref: Soref, R. A. & Bennett, B. R. Electrooptical effects in silicon. *IEEE J. Quant. Electron.* QE-23, 123–129 (1987)). However, today, almost 20 years after the demonstration, you cannot buy commercial silicon components based on this technique, and it is still unsure if the technique is good enough for commercial use.”

To negate the possibility of an electric current in this experiment, the scientists sandwiched a spacing layer made of silica glass between the silicon waveguide and the straining silicon glass on top. With this arrangement, no electric current travels through the waveguide.

“The advantage to using silicon compared with other electro-optics materials is the price,” says Jacobsen. “If you can use silicon, the price will potentially become very low.”

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