The butterfly effect: optical nanotechnology takes flight

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When scientists look for keys to unlock problems such as quantum teleportation or faster internet speeds, answers can sometimes be found in the natural world.

Controlling light at the nanoscale is necessary to develop the next generation of optical chips (integrated circuits which use light instead of electronics), but one of the missing pieces of the puzzle is a suitable device that could block or direct the flow of light based on its polarisation - until now.

In Nature Photonics today, we (along with colleagues from Australia and Germany) show how we achieved this goal by making artificial crystals with unique light polarising properties inspired by the wings of a butterfly.

Light is an electromagnetic wave that contains oscillating electric and magnetic fields. The polarisation of light is defined by the oscillation direction of its electric field.

![Wikimedia Commons](https://commons.wikimedia.org/wiki/File:Light_polarisation_diagram.png)

Polarisers found in sunglasses, for example, block horizontally polarised light, which helps remove glare from reflective surfaces.

One important polarising device is the polarising beamsplitter, which was invented in 1828, by Scottish physicist [William Nicol](http://en.wikipedia.org/wiki/William_Nicol_(geologist%29). Nicol's beamsplitter consists of prisms made from crystals that refract light differently based on their linear polarisation (vertical or horizontal). This optical property is known as birefringence.

As well as linear polarisation, light can also be circularly polarised. This is where the electric and magnetic fields rotate forming a helical path, as shown in the diagram below.

![Diagrams of right and left circularly polarised light. Wikimedia Commons](https://commons.wikimedia.org/wiki/File:Circular_polarisation_diagram.png)

However, a beamsplitter which splits circularly polarised light is much harder to create, as naturally grown crystals don’t significantly distinguish between left-handed and right-handed polarised light.

So to construct such a device one must create an artificial material: specifically, one with very strong sensitivity to circularly polarised light.

The design of such a crystal is quite a challenge and has been a sought-after goal of scientists for many years.

**Natural nanostructures**

The design for these new “photonic crystals” was inspired by nanostructures found within the wings of the *Callophrys rubi* butterfly, also known as the Green Hairstreak.

It has recently been discovered that this vibrant green butterfly obtains its brilliant colour through naturally-formed nanostructures within its wings. This colour is known as “structural colour” and differs from ordinary colours that occur from pigmentation.
Many other insect species have been shown to contain nanostructures that provide colour, but the *Calliphrys rubi* butterfly has one important difference: this butterfly’s wings contain an immense array of interconnected nanoscale coiled springs forming a unique optical material, one with extremely strong sensitivity to circularly polarised light.

We used this concept to develop our nanostructured crystal.

**Crystal construction**

To build these nanostructured crystals we used 3D laser nanotechnology. It is, essentially, 3D laser printing but with nanoscale resolution.

Using this technology we built a new nanostructured crystal using the nanostructures of the butterfly’s as a blueprint for our designs. The result was an artificial crystal with extremely high circular polarisation sensitivity.

Using this new crystal we were able to develop a polarising beamsplitter that split light of different circular polarisation. The device was a microscopic prism that contained more than 750,000 tiny polymer nanorods, yet was smaller than the width of a human hair.

When light was focused onto this tiny beamsplitter, it reflected off the beamsplitter if it was right circularly polarised but transmitted through if it was left circularly polarised.

This technology offers new possibilities for using circularly polarised light in nanophotonic devices.

Circular polarisation has been used in quantum teleportation and quantum optical computing. Biological molecules or even DNA can be analysed using circular polarisation.

Recent breakthroughs have shown that these new polarisation states can greatly improve the bandwidth of internet communications networks, already demonstrating terabit-scale speeds.

As to why the butterfly has such a complex nanostructure with circular polarisation sensitivity within its wings is still a question under debate. Hopefully advances in nanotechnology, such as this one, can unravel some of the mysteries.