

Scientists shed light on glowing materials

Research could lead to the development of enhanced bio-sensors for healthcare and more efficient solar cells and displays

Researchers at King's College London, in collaboration with European research institutes ICFO (Barcelona) and AMOLF (Amsterdam), have succeeded in mapping how light behaves in complex photonic materials inspired by nature, like iridescent butterfly wings. Scientists have broken the limit of light resolution at the nanoscale and delivered a fundamental insight into how light and matter interact, which could lead to the development of enhanced bio-sensors for healthcare and more efficient solar cells and displays.

Optical measurements of light waves at the nanoscale have always been limited by the resolution of the optical microscope, but researchers were able to break this limit using a new technique which combines electronic excitation and optical detection, to explore the inside of a photonic crystal and study the confinement of light. Working with a spatial resolution of 30 nanometers, scientists examined the structures at a resolution more than ten times smaller than the diffraction limit for light, revealing a greater understanding of how light interacts with matter to create, for example, the visible iridescence phenomena observed in nature on the wings of butterflies.

Dr Riccardo Sapienza, from the Department of Physics at King's, said: 'We were thrilled in the lab to observe the finer details of the photonic crystals that were simply inaccessible before. This is very important as it allows scientists to test optical theories to a new level of accuracy, fully characterise new optical materials and test new optical devices.'

The collaborative research has been published in the journal *Nature Materials*.

The team constructed an artificial two-dimensional photonic crystal by etching a hexagonal pattern of holes in a very thin silicon nitride membrane. Photonic crystals are nanostructures in which two materials with different refractive indices are arranged in a regular pattern, giving rise to exotic optical properties. Natural photonic crystals can be found in certain species of butterflies, birds and beetles as well as in opal gemstones where they give rise to beautiful shimmering colours.

The photonic crystal inhibits light propagation for certain colours of light, which leads to strong reflection of those colours, as observed when such materials 'catch the light'. By leaving out one hole, a very small cavity can be defined where the surrounding crystal acts as a mirror for the light, making it possible to strongly confine it within a so-called 'crystal defect cavity'.

The scientists based their research methods on a technique used in geology, called cathodoluminescence, whereby a beam of electrons is generated by an electron

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Published on Electronic Component News (<http://www.ecnmag.com>)

gun and impacted on a luminescent material, causing the material to emit visible light. Professor Albert Polman and his group in AMOLF modified this technique to access nanophotonics materials. He said: 'In the past few years we have worked hard with several technicians and researchers to develop and refine this new instrument.'

Dr Sapienza said: 'Each time a single electron from the electron gun reaches the sample surface it generates a burst of light as if we had placed a fluorescent molecule at the impact location. Scanning the electron beam we can visualise the optical response of the nanostructure revealing features 10 times smaller than ever done before.'

Professor Niek van Hulst, ICFO, said: 'It is fascinating to finally have an immediate view of the light in all its colours inside a photonic crystal. For years we have been struggling with scanning near-field probes and positioning of nano-light-sources. Now the scanning e-beam provides a local broad-band dipolar light source that readily maps all localised fields inside a photonic crystal cavity.'

With major advances in nanofabrication techniques it has become possible to construct artificial photonic crystals with optical properties that can be accurately engineered. These structures can be used to make high-quality nanoscale optical waveguides and cavities, which are important in telecommunication and sensing applications.

Dr Sapienza said: 'Our research provides a fundamental insight into light at the nanoscale and, in particular, helps in understanding how light and matter interact. This is the key to advance nanophotonic science and it can be useful to design novel optical devices like enhanced bio-sensors for healthcare, more efficient solar cells and displays, or novel quantum optics and information technologies.'

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