Scientists spin photons to send light in one direction

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(Phys.org) —Researchers at King's College London have achieved previously unseen levels of control over the travelling direction of electromagnetic waves in waveguides. Their ground-breaking results could have far-reaching benefits for the way light is controlled in optical waveguides and fibres, significantly improving integration, efficiency and speed.

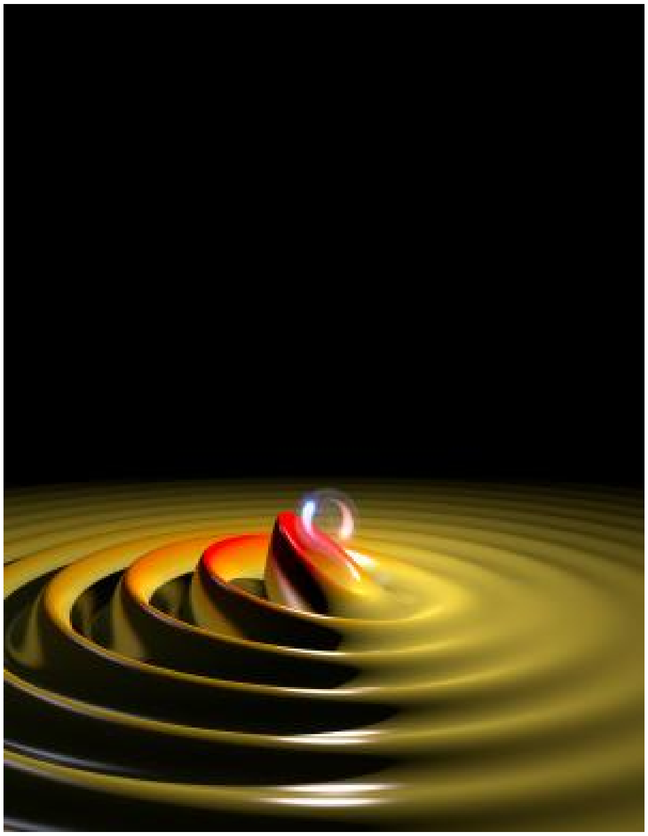
In a paper published today in *Science*, Professor Anatoly Zayats and his team, working with collaborators from Universitat Politècnica de València in Spain, show how their use of circularly polarised light - light containing spinning photons (fundamental particles) - and metallic nanostructures achieve a 'water wheel' effect to send light waves in a single direction along a metal surface. Their findings are surprising because such unidirectional waves have not been controlled in this way before. The research has profound implications for optical communications and information processing technologies.

Nanophotonics involves the study of light and how it interacts with structures at distances smaller than the wavelength of light. At this scale, interactions of tiny electric fields created by charged particles can have intriguing effects on light's movements. These effects often occur through interference, a phenomenon seen when two or more waves interact.

The scientists have improved on previous cumbersome attempts to use light to control the travelling direction of electromagnetic waves in materials. Many of these attempts have been inefficient. Until now, attempts to produce unidirectional light have only worked using single wavelengths and have not allowed for the resultant wave's direction to be easily switched.

Professor Zayats, from the Department of Physics at King's, said: 'Wave interference is a basic physics phenomenon, known for many centuries, with myriad applications. When we observed that it can lead to unidirectional guiding when spin carrying photons are used, we could not at first believe that such a fundamental effect had been overlooked all this time. We now work on developing its applications in nanophotonics and quantum optics.'

The team used circularly polarised light to illuminate a small metal structure. The spinning photons in the polarised light caused the electrons in this nanostructure to move in circles, clockwise or anticlockwise depending on the direction of the photons' spin. If this structure is then brought close to an optical waveguide or a metal surface , waves in these materials moved in one selected direction only. This type of control, using circular polarisation, has not been achieved before.



Circularly polarized dipole over a metal surface, exciting surface plasmons unidirectionally. The height of the metal surface represents the surface charge density. Credit: Francisco J. Rodríguez-Fortuño

If the polarisation direction of the light is changed, the ultimate direction of the excited wave can be reversed. Researchers have compared the effect to a 'water wheel' operating in a river, with the wheel being the small metallic structure and the water being the stream of light.

The unidirectional waves arise through interference in the 'near field'. This electromagnetic interference is similar to that seen when two or more waves meet on the surface of a pond. The 'near field' refers to the proximity of the waveguide to the nanostructure illuminated with the polarised light.

Mr Francisco Rodríguez Fortuño, PhD student and the lead author of the *Science* article, said: 'We have presented an entirely new concept, surprisingly simple, that can be used as the foundation of various novel devices. The phenomenon holds promise for spin sorting of photons, processing of polarisation encoded information and much more.'

More information: "Near-Field Interference for the Unidirectional Excitation of Electromagnetic Guided Modes," by F.J. Rodríguez-Fortuño et al. *Science*, 2013.
www.sciencemag.org/content/340/6130/328.abstract

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