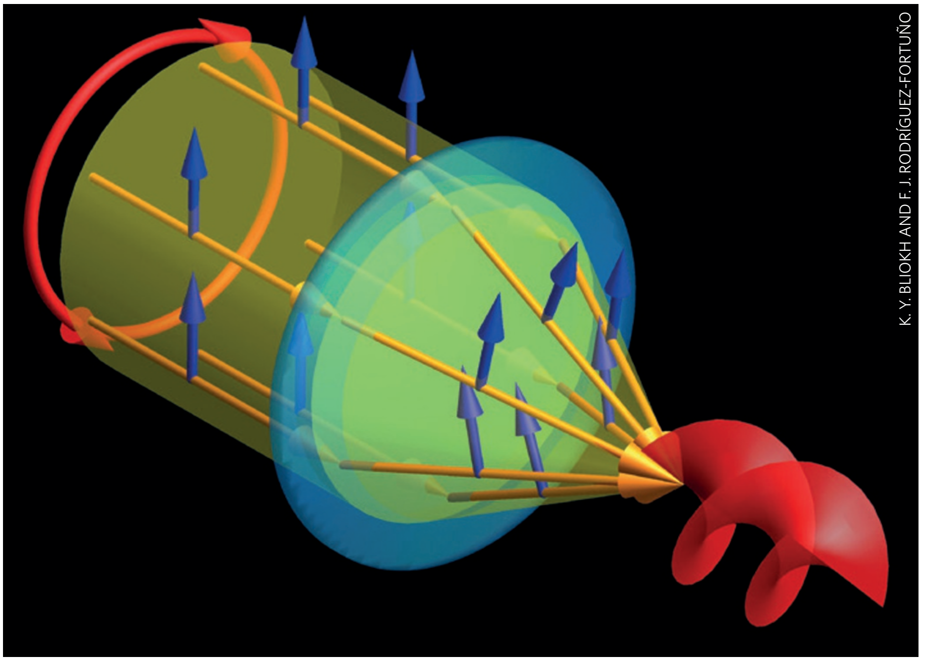
A wonderful spin

First studied more than a decade ago, the field of spin–orbit interactions of light has accelerated in recent years and is now being exploited in nanophotonics and the generation of complex optical fields.

When light travels approximately in a straight line, it also rotates around its own axis. This rotation can be revealed by the interaction of the light beam with matter. There are two different forms of rotation of a light beam, one based on its polarization and the other its spatial field distribution, particularly its wavefront shape. These two forms of rotation correspond to two different forms of angular momentum, which are light spin angular momentum and light orbital angular momentum, respectively.

Spin–orbit interactions arise from the interaction between the polarization and the spatial structure of an optical wave, mediated by suitable optical media. They are, in fact, not rare and also occur in standard paraxial optics, but their effects are so small that they are often neglected for most practical purposes. Because of this, only about ten years ago research on spin–orbit interactions of light started to grow, and it is just very recently that novel fundamental and applied results related to spin–orbit optical phenomena have started to accelerate.



This *Nature Photonics* focus issue is on precisely this topic. A collection of articles, including a Review, Progress Article and a Commentary, aims to provide a deeper understanding and new insights into this young flourishing field.

Spin–orbit interactions are inherent in many basic optical processes. On page 796, Konstantin Bliokh and co-workers review the fundamental origins and important applications of the main spin–orbit interaction phenomena in optics. Topics covered are the spin Hall effects in inhomogeneous media and at optical interfaces, spin-dependent effects in nonparaxial (focused or scattered) fields, spin-controlled shaping of light using anisotropic structured interfaces (metasurfaces), as well as spin-directional coupling via evanescent near fields. They remark that spin–orbit interactions of light play a crucial role at subwavelength scales and structures in modern optics.

Recent advances in optics have led to the notion of spinning electromagnetic fields carrying angular momenta transverse to the direction of motion — analogous to a spinning mechanical wheel. On page 789, Andrea Aiello and co-workers review recent developments of optics with light carrying transverse spin. They anticipate that this field will enable numerous applications in nano-optics, biosensing and near-field microscopy, including three-dimensional control over atoms, molecules and nanostructures, and allow for the realization of chiral nanophotonic interfaces and plasmonic devices.

The Commentary by Filippo Cardano and Lorenzo Marrucci on page 776 provides an interesting overview of the emerging photonics applications relying on the spin–orbit interactions, which can be divided into three main groups: generation of structured optical fields; enhanced optical manipulation and detection of small particles; and control of the optical wave propagation at the micro- and nanoscale via the light spin.

It is known that conservation of linear momentum of light leads to the well-known radiation pressure, which usually leads to a 'push force' in the direction of the wave's propagation. In certain circumstances, this conservation law can also result in negative forces, referred to as 'tractor' beams. It is also known that light carries angular momenta, spin and orbital. In particular cases, the conservation of angular momentum induces torques. During interaction with matter, there can be transformations between the spin angular momentum and the orbital angular momentum — this is the origin of the spin Hall effect of light. Making use of this effect, in a Letter on page 809, Sergey Sukhov and colleagues demonstrate theoretically and experimentally that the transformation of spin into orbital momentum leads to a fundamentally new type of force acting transversally to the direction of propagation, showing that spin–orbit interactions also have mechanical consequences.

The potential of spin–orbit optical interactions in photonics applications has not yet been exploited fully. When combined with nanophotonics and metamaterials, spin–orbit optical interactions could achieve novel functionalities in photonic systems. They could also be linked to the emerging field of topological photonics leading to novel results and applications. Other potential areas where spin–orbit interactions of light can be of use include quantum information processing and ultrafast optics manipulations. Let's wait and see how this young field is going to spin the world of optics and photonics. ❐